IRON AND STEEL ENGINEER

J. F. KELLY, Editor

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W. E. MILLER, Elec. Supt., Bethlehem Steel Company, Johnstown, Pa.; Chairman Monday evening Reception.

H. E. DAVIS, Elec. Supt., Interstate Iron & Steel Company, South Chicago, Ill.; Chairman Registration Committee.

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B. R. SHOVER, Consulting Engr., Pittsburgh, Pa.; Chairman Special Bearings Committee of AI&SEE.

CITY OF PITTSBURGH
OFFICE OF THE MAYOR

CHARLES H. KLINE
MAYOR

April 21st, 1927.

Association of Iron & Steel Electrical Engineers,
Empire Building,
Pittsburgh, Pa.

Gentlemen:-

In the name of the people of Pittsburgh, I welcome you as you gather here to hold your Twenty-third Annual Convention.

The selection of Pittsburgh as a meeting place for men in your profession, could not be more appropriate.

Any history of your industry which does not accord to Pittsburgh a position of supreme importance would be not only inaccurate but absurd.

Because of her past and present, her name is revered among the makers of iron and steel. For almost a century she was the very heart of industrial development in America.

With all respect to her competitors I know you appreciate what Pittsburgh has done for the iron and steel industry. Her sons and daughters in turn appreciate what the iron and steel industry has done for Pittsburgh.

In some respects the present situation visualizes Pittsburgh, as the mother, opening her arms once more to members of the steel family. In a sense, we feel you are all just coming home. As far as Pittsburgh is concerned you come to us, not as strangers but as relatives.

In such a spirit Pittsburgh bids you to enter and abide with us in an atmosphere of affection and goodwill.

Sincerely yours,

Charles H Kline

MAYOR

R. D. ABBISS, Spec. Engr., Carnegie Steel Company, Author "Recent Boiler Plant Installation at the Edgar Thomson Works, Carnegie Steel Company.

W. W. GARRETT, Engr. of Tests, Tennessee Coal Iron & Railroad Co., Birmingham, Ala., Author "Investigation in Operating Cost Reduction."

A. N. CARTWRIGHT, Supt. Power Div., West Penn Power Co., Author "Safe Practices in connection with the Operation of High Tension Power."

F. H. BUHLMAN, Chief Engr., Rollway Bearing Co., Author "Factors Governing the Design of Roller Bearings for Roll Necks."

C. J. KLEIN, Engr., United Engineering & Foundry Co., Author "Bearings for use in Rolling Mills."

J. D. DONOVAN, Supt. Mech. and Elec. Depts., Central Alloy Steel Corp., Author "The Superintendent's and Foreman's Responsibility in Safety and Rehabilitation."

WARD HARRISON, Director of Illuminating Engineering, National Lamp Works of General Electric Company, Author "Fifteen Years of Steel Mill Illumination—What Change."

HARRY A. WINNE, Engr. Dept., General Electric Company, Author "The Application of Synchronous Motors in Steel Mills."

A. R. LINTERN, Floor Manager, Iron and Steel Exposition.

(Continued on Page 321)

OFFICIAL PROGRAM

Twenty-third Annual Convention

and

Iron and Steel Exposition

SYRIA MOSQUE, PITTSBURGH, PA.
JUNE 13TH TO 18TH, 1927.

Registration, Business Session and Technical Sessions will be held at Pittsburgh Athletic Association Annex which is the Old University Club.

MONDAY, JUNE 13TH

9:00 A. M.
Registration

9:30 A. M.
Business Session
S. S. Wales, Chairman

10:00 A. M.

"Electrical Heating in the Iron and Steel Industry." By AI&SEE Electrical Heat Committee, Geo. H. Schaeffer, Chairman.

11:30 A. M.

"Electrical Developments in the Iron and Steel Industry." By AI&SEE Electrical Development Committee, W. H. Burr, Chairman.

12:30 P. M.

Informal Reception and Luncheon for Members and Guests of AI&SEE. To take place at Annex of Pittsburgh Athletic Association.

1:30 P. M.
C. L. Baker, Chairman

Session of Safety Engineering Division of AI&SEE.

"Safe Practices in Connection With the Operation of High Tension Power," by A. N. Cartwright, General Supt. Power Division, West Penn Power Company, Pittsburgh, Pa.; Geo. E. Gramm, Electrical Engineer, H. C. Frick Coke Company, Scottdale, Pa., and Thomas E. Hughes, General Foreman, Carnegie Steel Company, Duquesne, Pa.

2:30 P. M.

Discussion by Safety Division and Electrical Engineers and Superintendents of Iron and Steel Plants, Central Stations and Mines.

7:30 P. M.
Official Opening of Iron and Steel Exposition.

9:00 P. M.
W. E. Miller, Chairman.

Informal Reception and Dance for Members and Guests. Annex of Pittsburgh Athletic Association.

TUESDAY, JUNE 14TH

B. R. Shover, Chairman.
10:00 A. M.

Symposium: "Anti-Friction Bearings for Heavy Duty Steel Mill Applications With Particular Reference to Roll Necks," by F. W. Cramer, Asst. Elec. Supt., Bethlehem Steel Company, Johnstown, Pa.; C. J. Klein, Engineering Dept., United Engineering & Foundry Company, Pittsburgh, Pa.; F. H. Buhlman, Engineering Dept., Rollway Bearing Company, Syracuse, N. Y.; E. C. Gainsborg, Engineering Dept., SKF Industries, Inc., New York., and Fred Waldorf, Engineer, The Timken Roller Bearing Company, Canton, Ohio.

11:45 A. M.

"The Application of Synchronous Motors in Steel Mills," by Harry A. Winne, Industrial Engineering Dept., General Electric Company, Schenectady, New York.

WEDNESDAY, JUNE 15TH

W. J. Harper, Chairman
10:00 A. M.
Combustion Engineers' Day.

Auspices Combustion Engineering Division AI&SEE.

"Recent Boiler Plant Installation at Edgar Thomson Works, Carnegie Steel Company, Braddock, Pa." By R. D. Abbiss, Special Engineer, Carnegie Steel Company, Braddock, Pa.

11:30 A. M.

"The Flat Suspended Open Hearth Roof," by A. L. Foell, Chief Engineer, Donner Steel Company, Buffalo, N. Y.

7:00 P. M.
A. G. Place, Chairman.

Annual Dinner Dance for Members and Guests of AI&SEE at Ball Room Schenley Hotel.

7 P. M.
Dinner

9 P. M.
Concert

Anna Case, America's Most Celebrated Soprano, former Metropolitan Grand Opera star.

10 P. M.
Dance

THURSDAY, JUNE 16TH

10:00 A. M.

"Electrical Installations at New Structural Mills, Homestead Steel Works, Carnegie Steel Company, Munhall, Pa.," by C. A. Menk, Electrical Superintendent, Carnegie Steel Company, Munhall, Pa.

THURSDAY AFTERNOON

"Inspection Trip to New Structural Mills of Homestead Steel Works of Carnegie Steel Company, Munhall, Pa." Make your reservation by card.

FRIDAY, JUNE 17TH

A. J. Standing, Chairman.
10:00 A. M.

"Fifteen Years of Steel Mill Illumination—What Change?" by Ward Harrison, Director, Illuminating Engineering Division, National Lamp Works of G. E. Company, Cleveland, Ohio.

FRIDAY AFTERNOON

Golf Tournament, Edgewood Country Club. Details may be had from Bulletin Board at Syria Mosque.

SATURDAY, JUNE 18TH

Maintenance Employes' Day at Iron and Steel Exposition from 10:00 A. M. to 10:00 P. M.

MANUFACTURERS WHO WILL BE REPRESENTED AT IRON AND STEEL EXPOSITION

	Booth No.
Air Preheater Corporation	192
Air Reduction Sales Co.	1–2
Allegheny Steel Co.	158
Alliance Machine Co.	88
Allis Chalmers Mfg. Co.	45–46
American Brown Boveri Co.	111 to 119
Andrews Bradshaw Co.	138–141
Appleton Electric Co.	166–167
Automatic Reclosing Cir. Breaker Co.	62
Bacharach Industrial Instrument Co.	78–79
Baker Raulang Co.	127
Barney Machinery Co.	171–172–160
Bartlett Hayward Co.	86–87
Earl B. Beach Co.	13
Bearium Bearings, Inc.	15
Benjamin Electric Mfg. Co.	40
The Bristol Co.	61
Bussmann Mfg. Co.	123
Blast Furnace & Steel Plant	189
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EDITORIALS

Indirect Effects of Steel Mill Electrification

By S. S. WALES*

THERE are many primary reasons for the present rapid advance in steel mill electrification, which have been proving their value for the past twenty years until now it is impossible to disregard this accumulated evidence. No method of power application, including production, distribution and control can compete with it in convenience and safety even if we disregard actual money economy.

The Centralization of the power plant, with large boiler units and modern turbine generators, guarantees efficient production of power, and the short steam lines reduce condensation and leakage losses

S. S. WALES

to a minimum. The use of high tension Electric Power transmission, and the ease and economy with which this voltage can be reduced to fit each application by means of modern transformers eliminates long exposed steam lines, with their inherent disadvantages.

The electric motor with its uniform torque throughout a revolution, supplies an equipment which cannot be stalled under ordinary working conditions, or slowed down by a long continued load as in the case of reciprocating engines, which rely on their flywheels to carry them through. The ease of lubrication and inspection with the simplicity of construction decrease the labor in repairs and maintenance.

There are however, many secondary advantages to which attention is seldom called, probably because they cannot be readily translated into dollars and cents savings.

The predetermining and systematizing of a series of operations, to be carried on with the utmost speed compatible with the results desired, is a most valuable asset to the electrified tool. Acceleration and deceleration can be carried on methodically and safely no matter under what excitement that the actual operator may be laboring. The repetition of a sequence of steps, once proved to best fit the rolling condition can be repeated accurately and indefinitely, but still can be interrupted at any point by the operator if necessary.

The whole equipment can be worked to its greatest safe capacity because safety limitations are imposed on the apparatus in the original design, so that the stresses encountered cannot exceed the machinery ability to resist. In other words, the intelligence and experience of the engineering department can be embodied in the active operation of the machinery, as well as in the design of the inert machine itself, and the actual production of steel rolled becomes a combination of this engineering knowledge and the skill of the experienced operator.

Another advantage which is hard to estimate in money values, is the concentration of control, in the hands of one person, of several operations which were formally distributed among several individuals who had to co-ordinate their efforts. An illustration in point is the assembly under direct control of the roller, of the screw down, front and back mill tables and main rolls on a reversing mill, which eliminates the possibility of a misunderstanding between the roller and the table operator, and the engineer. The control which is now almost entirely by means of small relay currents, handled through light easily moved pilot switches, relieve the operator of much heavy work which was formally quite prominent in handling hydraulic levers and reversing engine controls.

In addition to the above the ability of electric power to draw a continuous curve of its performance, gives a constant check on continuity of the mill operation which is absolutely accurate. These wattmeter curves also allow the fraction losses to be checked at once after a roll change or change in lining of the mill, for different weights of section, in non-reversing mills, where it is possible to unknowingly impose extra loads on a steam driving roll train by too much neck pressure. The curves also show how the work is distributed among the various passes and can be of great assistance to the roll designer.

It is quite probable that the "extra tonnage," which always develops above the calculated capacity with an electrified mill, may be due to the sum of these secondary advantages, which taken together become of considerable importance.

*President Association of Iron & Steel Electrical Engineers and Chief Elec. Engr. of Carnegie Steel Co., Pittsburgh, Pa.

Replacement of Obsolete Equipment

By A. J. STANDING*

THE expression "Obsolete Equipment" is often used perhaps without a very clear and definite idea as to its exact meaning to industrial operators. The word obsolete is defined as "gone out of service." Industrial Equipment still in service must be regarded by us as obsolete when its operating and maintenance costs materially exceed the similar costs of improved equipment. When the equipment is finally pronounced too costly for further use, it must be replaced if operation is to be continued.

The problem of determining the economic point in the life of equipment at which it becomes justifiable and advisable to replace the old with new is not easily solved in any industry; and especially is this true of the equipment normally under the jurisdiction of Steel Mill Maintenance Departments because of the variables present. We can readily see how, in the quantity production of duplicate materials, it may be entirely feasible to confine this problem within very definite limits and to actually derive an empirical formula based on production and costs which will solve the problem for a given operation.

We find in the Steel Mills that one of the hardest phases in the solution of this problem of replacement is the assembling of facts to demonstrate the necessity of appropriations for the purchase of new equipment. Often times it seems cheaper for us to waste the "old dollars" gradually even if surely than to spend "new dollars" for the replacing equipment to stop this waste. The uncertainties of business with respect to future volume and earnings affect the situation to the extent that during periods of reduced operation when there is ample time and opportunity to make the necessary changes, funds are, as a rule, not available. Vice versa, in times of peak operation when funds are more readily available, there is neither time nor opportunity to replace equipment that is still in operating condition or can be again quickly put in operation.

Somewhere between these extremes we must work out the solution to this problem as it applies to our Plant and the existing operating conditions as we see them. Let us look at some of the variables present, other than percentage of operation, which very materially affect the proper solution of our problem.

The cost of production must be given first place, therefore let us analyze some of the features that have a distinct bearing on this basic item.

The ultimate cost of production in the Steel Industry involves many factors that are not controllable by the maintenance departments. There are, however, two very important items directly in the maintenance field that are intimately connected with production costs. These are:

Continuity of operation.

Maintenance cost connected with this operation.

The answer to our problem: "when should obsolete equipment be replaced?" is inseparably connected with the above mentioned factors.

Naturally the care and thought exercised in making the original installation have a considerable bearing on both subsequent operation and maintenance costs if the operating unit under consideration continues to produce the material for which it was designed. Our experience teaches us that this is an important proviso because it frequently happens that varying market conditions necessitate the operation of equipment under widely different conditions from those anticipated when the original layout was made.

The very severe nature of service demanded under schedules of continuous operation involves repairs and replacement by spares of those parts of the equipment subjected to the greatest strain and wear. With the increasing age of equipment, our ability to secure these spare parts from the Manufacturers is limited by changes in design, production, and cost of more modern equipment. Consequently the cost of spare parts for older equipment involves a continually increasing penalty. The Manufacturers are at times reluctant to supply parts for equipment no longer in standard production.

It frequently develops that advances in equipment design enable us to realize enough saving in labor and production costs to clearly justify the change. However this is not always the case and there are many instances where we could economically continue to operate equipment at satisfactory production rate and cost, if we could obtain the necessary spare parts quickly and cheaply.

It is the duty of the operating maintenance Superintendent to prepare the necessary data to so present the case to the Management as to answer in advance all questions that may arise regarding the advisability of a given expenditure for replacing equipment.

The data required to make up such recommendations consist of definite delay records, maintenance cost figures; a forecast of the probable future demands on the equipment in question; and an estimate of the possible saving and increased production reasonably to be expected from the proposed substitution. The deciding factor, however, will be the correct interpretation of this data in the light of the experience of the maintenance Superintendent; because only experience can enable him to make a fair estimate of the operating chances that can safely be taken for any length of time without jeopardizing the existing operation.

The possibilities of reclamation of worn equipment can be fully realized only when studied with a background of experience which covers all fields of salvage; and we are not justified in finally scrapping an expensive piece of equipment until we have exhausted all reasonable methods of repair.

In conclusion we may safely say that the solution of the problem of replacing obsolete equipment in the Steel Industry resolves itself into the comprehensive study and analysis of the several factors we have discussed when viewed from the standpoint both of the operation and the future policy of the Management with regard to the Plant or unit in question.

*Elec. Supt., Bethlehem Steel Co., Saucon Plant, Bethlehem, Pa.

ELECTRIC POWER IN THE IRON AND STEEL INDUSTRY—GENERATION OR PURCHASE?

By GORDON FOX*

ABOUT two-thirds of the electric power consumed by the iron and steel industry is generated in its own industrial power plants, about one-third of the total consumption being purchased from public utilities. The primary justification of power generation by the steel plant is the utilization of by-product fuels and waste heat. The principal by-product fuels adapted particularly for power generation are blast furnace gas and coke breeze. The principal sources of waste heat are the open hearth furnaces. An analysis of costs generally indicates that, insofar as these waste fuels and heat sources extend, the investment in equipment for their utilization is amply justified and the resulting power costs are such that public utilities cannot successfully compete. The exceptions to this rule are infrequent.

Another primary reason for the existence of a power plant in the combined iron and steel works is the need for services other than electric power. Blast furnace blowers are almost universally gas or steam driven and there seems little likelihood of any general adoption of electric drive for this essential and exacting service. Few extensive blast furnace and steel works operators are disposed to depend solely upon electrically driven pumps for essential water supply. Process steam is required to some extent.

If it is granted that a power and general service plant is a necessary adjunct of the works, the question then becomes one involving the generation of electric power, not as an isolated enterprise but as an addition to an essential provision. The fact that the electric generation is an addition to a necessary plant, affects the situation fundamentally thus:

The additional equipment necessary to electric power generation can be provided at a materially lower investment than in case of aa isolated enterprise.

The operating cost incident to the electric power generation, in the form of additional attendance, is less than would be associated with a separate operation.

The electric generation enables the complete utilization of by-product fuels and waste heat and absorbs the differences between variable fuel supply and varying service demands.

Some supplementary firing of other than by-product fuels is commonly necessary in the local power plant because such fuels are not available continuously nor in constant amount. Supplementary fuel firing not only permits all services to "carry on" during lapses of by-product fuels; it also enables the full utilization of equipment which may be installed of sufficient capacity to utilize by-product fuels at their times of maximum availability.

The extent of use of supplementary fuels and the generation of electric power therefrom is a question which must be determined in the individual case. It is here that the public utility may function. The utility may perform three services in connection with an industrial power plant as above situated, viz.:

It can supply electric power required in excess of that which can be developed from by-product fuels and waste heat sources, attended by a minimum of supplementary fuel firing.

It can provide standby protection.

It can serve as a market for electric power available at the industrial plant in excess of plant needs.

In order to function as a supplementary supply of electric power the utility rate must compare favorably with the cost of generating additional power and with fixed charges attendant upon the additional plant necessary to that end. Needless to say, a low rate is necessary to meet these requirements but some utilities seem to find this business attractive.

Reliability is an essential attribute to steel mill power. To this end an isolated plant must carry reserve capacity. If the utility system is such that it can provide a standby source of power protecting the local plant at a rate comparable with the fixed charges incident to the investment in reserve equipment, such service is attractive. The inter-connections accessible to the utility should render such protection possible at a competitive cost and such service is now being successfully supplied.

The surplus power which the steel mill plant may deliver to the utility is necessarily dump power and must be evaluated as such. Nevertheless, it may prove a material benefit in enabling the complete utilization of by-product fuels and waste heat which could not be more effectively used.

*Elec. Engr., Freyn Engineering Co., Chicago, Ill.

PROGRESS IN THE STEEL INDUSTRY

By W. H. BURR*

LOOKING backward too frequently is not advisable, but for the purpose of comparison certain benefits can be obtained. In going over the records of new main roll drives installed during the past year one cannot help but be impressed with significance of the fact that the manufacturers of electrical equipment produced approximately 150 main roll drives during the past year, for use in United States and Canada.

When we consider the many sources from which the material required for construction of these motors is derived we can realize what a tremendous influence the condition of the steel industry has on the general business conditions of this country.

The cost of labor in the production of steel has been one of the principal reasons for the rapid development of motor driven steel mill equipment. To reduce this cost, equipment has been developed which is constantly reducing the number of men required for the production of steel. As a direct result of the installation of automatic equipment and consequent reduction in man power, there is established a demand for more highly skilled mechanics and electricians to maintain and repair this automatic machinery.

When we learn that the control equipment on screw mechanism has been perfected to a stage where three screw down controllers are controlled by a single master switch, we wonder how long it will be before we can select the proper size ingot, push a button, and set in motion machinery which

*Elec. Supt., Lukens Steel Co., Coatesville, Pa.

will turn out a finished steel product ready for the shipping department.

The development of ball and roller bearings is responsible for a considerable saving of power, which is one of the controllable items in the cost of steel. The application of roller bearings to main rolls has resulted in a very substantial saving of power. I am of the opinion that this saving will amount to 30% of the total power required on main roll drives.

If this proves to be the case the use of roller bearings on main rolls will become general in a short time.

It is generally conceded that electricity has for some time effected sufficient savings to warrant discarding other forms of main roll drives and to justify the now growing demand for better and more efficient motor drives.

The past year has seen more development in the application of electricity to the steel industry than in any previous year, and there is every reason to believe that the coming year will even surpass the one which is now history.

THE SUPERINTENDENT'S AND FOREMAN'S RESPONSIBILITY IN SAFETY AND REHABILITATION

By J. D. DONOVAN*

EFFORTS to promote safety and organization for safety in industry frequently fails because Superintendents and Foremen cannot be induced to co-operate in this great humanitarian work. These men attempt to justify their refusal to organize for safety by claiming that they have delegated this duty to some understudy, or that they are too busy with operations to fulfill their obligation in conserving the lives and limbs of those employees intrusted to their care.

The modern and up-to-date Superintendent or Foreman of today is the man who keeps his production force intact, and losses of all kinds at a minimum, and he is also the man who insists that the men under his supervision must at all times, and under all circumstances, comply with the safety rules, and never indulge in dangerous practices.

It is apparent that in the rapid strides of modern safety engineering, much work of an educational character must be undertaken, in order to accomplish the most practical results, and therefore the greatest degree of co-operation must of necessity exist between Superintendents and Foremen. Safeguarding of machinery alone will not eliminate accidents. The greatest thing we need in industry is a combination of circumstances, the most important of which is educating the average person along accident prevention work. I believe that every employee should participate in this work from the head of the concern down to the last individual employed by the concern, and all should appreciate equally their responsibility in the work.

The safety movement was fully recognized by our Corporation several years ago with the result that it is now a part of the operations and on an equal plane with any other operating department. At the inception of the movement the overhead was greatly increased by installing costly but practical safety appliances and devices, and eliminating dangerous practices. What has been our return for such expenditures? Our Accident Severity for the year 1924 was reduced 46% as compared with the year 1923, and a further reduction of 7½% was made during the year 1925, as compared with 1924, and another reduction of 8% during 1926, as compared with 1925.

The methods used to accomplish this record in our plant are very simple and are based on good common sense. Dangerous places are guarded, and dangerous practices were, and are now, prohibited. Through the efforts of our Superintendents and Foremen every man was told and taught the whys and wherefores of safety when the campaign for safety was launched in our plant in March, 1923, and a systematic educational campaign against accidents has been followed ever since.

Safety First is our policy, for if this were not true, we would value money above the lives, limbs, and health of our workmen. However, you will find that safety work, being a study of the right and orderly way to do things, will also without a doubt increase efficiency and production as well as aid humanity.

Safety First is not alone a humanitarian movement, but a practical medium of business extension, and it is right here where many department heads have missed the point. Whether you know it or not, Safety is a matter of dollars and cents, as well as the conservation of human lives and limbs, and it is for this reason that you are prompted to its support from a very selfish standpoint if you hope to operate your department efficiently and economically, and if you expect to keep in step with the up-to-date and aggressive Superintendent or Foreman of today, as Safety is no longer a fad, but something that is ingrained in the right conduct of business itself.

Another important phase of this work, which cannot be stressed too emphatically, is that of Rehabilitating those employees, who through an unfortunate accident, cannot perform the duties of their former occupation. It is the aim of our corporation to do everything possible to avoid accidents to our employees, but if they are injured, see that they receive the best medical attention, and that they are placed in employment suitable to their injury and capacity.

Our aim is to give them a commercial opportunity suitable to their special needs and ability, yet in no way created especially for them; to maintain this opening on a strictly business basis, where each man shall hold or lose his job according to the merits of his work. By so doing, all taint of charity, which is as abhorrent to an injured person as to any one else, is removed from his mind. By such work a large number of our citizens can be rehabilitated and made useful members of Society, as well as very profitable to industrial concerns.

This work in our corporation is done by a Rehabilitation Committee, composed of a member from each Division of the Corporation, and the injured employees are given every opportunity to advance and make a livelihood.

Years of experience have demonstrated to us that great benefits and advantages are to be gained

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through systematic accident prevention and rehabilitation work on the part of Superintendents and Foremen. We are convinced that a well managed, up-to-date and smoothly run Safety organization is very essential to our success as operating department heads as well as to our Corporation and its employees.

If we are to continue our development without sacrifice, and have safe industries in America, every Superintendent and Foreman should feel that the responsibility for safety is on them. Accidents are unnecessary and can be reduced. Safety is an operating problem. If accidents are to occur in great numbers in any particular industry, it would be well to study the situation and locate the trouble. What better condition in our industrial life could be wished for than contented men with happy homes and highly efficient plants in which to work?

ELECTRIC HEAT TREATING FURNACE OPERATING DATA

By R. W. HELLER*

SOME interesting operating data on various types of Electric Heat Treating Furnaces have been gathered from several manufacturing companies, and are presented here to show the progress which has been made in the electric heating field.

A 90 kilowatt continuous type furnace is in operation at the Federal Drop Forge Company to heat and treat small miscellaneous forgings at 1500 degrees Fahrenheit. The work is carried through the furnace on trays, and a gross production of 13¼ pounds per kilowatt hour or a net production of 8½ pounds per kilowatt hour is obtained.

This furnace replaced an oil fired continuous furnace because of the high maintenance cost and loss of time due to repairs on the latter and because a greater flexibility of temperature control could be obtained in the electric furnace.

At a well known tool steel company a 210 kilowatt car type furnace is annealing carbon tool steel bars at 1430 degrees Fahrenheit. A 10 ton charge is annealed at one time with a comsumption of 280 to 300 kilowatt hours per ton. The furnace replaced coal fired equipment because of the necessity for a uniform Brinell test throughout the length of the bar. The total annealing cost per ton has been reduced and there has been no maintenance on the furnace since its installation fourteen months ago.

The J. H. Williams Company of Buffalo, New York, are operating a 126 kilowatt rotary hearth type furnace for hardening alloy steel parts. A production of 1000 pounds per hour at 1525 degrees Fahrenheit is obtained and an estimated production of 10 pounds per kilowatt hour. The furnace is improving the quality of the parts and reducing rejections.

A 300 kilowatt furnace is now annealing five to six tons of steel castings per charge at the Milwaukee Steel Foundry Company with a production of 10 pounds per kilowatt hour. The economy and uniformity of the annealing is the reason this jobbing foundry resort to electric heat. A maintenance charge of 25 cents per ton is placed against the furnace.

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Three years ago the first unit consisting of two furnaces was installed at the Columbia Tool Steel Company, Chicago Heights, Illinois, for annealing tool steel bars. Two furnaces have been installed each year since until at present six furnaces are in operation. Each furnace is rated at 110 kilowatts and the average gross charge annealed in each furnace is 5700 pounds (work is being packed). The furnaces are arranged for controlling both the heating and cooling cycles and the ability to repeat this program has been one of the outstanding features of this equipment. Test information indicates a consumption of 351 kilowatt hours per ton of annealed steel including the boxes.

The maintenance of the equipment is not known but a flat rate of 10 cents per ton is charged. The user states they have been able to maintain an exceedingly high quality and exact uniformity in their production, which was not possible with the fuel fired equipment.

One of the large steel companies is hardening steel track bolts in a 250 kilowatt continuous pusher type furnace. Three of these furnaces are producing approximately 2,500 pounds per hour each with an economy of 11 pounds per kilowatt hour. The outstanding feature of the product of this furnace is its improved physical property and uniformity throughout.

These are typical installations, duplicates of which are operating in other industrial plants of similar character. The industrial electric furnace has proved itself and has long been a commercial reality.

RECORDING INSTRUMENTS IN THE STEEL INDUSTRY

By MARTIN J. CONWAY*

A STEEL plant operating without recording instruments is very much similar to a department store devoid of cash registers. Modern steel plant accounting demands accurate records of its various operations consuming fuel, electricity, steam, water and compressed air, all of which can be measured with a fair degree of accuracy. Until recent years the steam plant operation was the only one carefully checked and the use of recording instruments in the steam plant has done much toward giving us the marked progress in design and efficiency of this service department. There now remain few steel plant operations which cannot be graphically checked with some form of recording device.

Most blast furnaces recently built or remodeled have been completely equipped with recording instruments from temperature recorders on the stove stacks to tachometers on the blowing engines. Open hearth and soaking pit furnaces can be equipped with reversal recorders thereby preventing undue abuse to refractory and saving fuel, in addition to protecting the product in process.

While it is not practical to reverse steel plant furnaces with the clocklike precision used on by-product coke ovens, the installation of reversal recorders will undoubtedly lengthen the life of the furnaces and help in fuel conservation by keeping the operators "on their toes."

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The power input used by the steel plant prime movers can be graphically recorded and is no longer an assumption.

Recording instruments in conjunction with heat treating furnaces are a necessity in these days of supercritical customers. Economy in manufacture plus quality of product can best be obtained by the manufacturers who are in possession of their operating data in the form of records, which can be readily analyzed.

Recording devices wisely chosen, properly installed and maintained, form an important item of the steel plant property and if used to advantage will have a greater investment value than any other steel equipment.

ENGINEERING INVESTIGATION IN OPERATING COST REDUCTION

By W. W. GARRETT*

IN the program of endless progress and advancement of the steel industry, in all of its many and varied fields of endeavor, the, "What will it cost," inquiry enters more and more into every detail and phase of the development of all great enterprises. Each succeeding year brings with it a greater demand for steel products. This new era of a world of more closely associated nations assures that competition among manufacturing companies will be greater.

No questions are more vital to the successful operation of any manufacturing industry than those that can be settled by investigation and study of the cost reduction engineers. The word engineers here refers to all classes of men engaged in the management, development, design, planning, operation, and cost estimating of any of the many phases and varied details of steel making as well as of other fields of manufacturing. Cost study has become a science in itself in the industrial world and all classes of engineers are required in its service.

As the industries of the world continue to grow, competition has to be keenly and carefully planned in all kinds of manufacturing. No business can thrive very long unless its policies are governed by the "What will it cost" inquisitive mind in every phase of its endeavor.

Each new idea in the development and operation of the steel mills must be carefully studied, and its relation to cost of production definitely known. Each year sees additional mills and factories erected. Each new plant or unit has adopted, in nearly every instance new or more modern methods of production. The questions naturally arise: What did it cost to produce under the old scheme of operation? What will it cost to operate and manufacture with the new and more modern equipment, whose first cost naturally is the greater? It must be remembered in this connection that with the old methods of production, the mills made money. If the new idea does not produce more tonnage, and at a less cost, where is the trouble? In his investigations of old factories the cost engineer must know how to locate leakages quickly. He must know what to do when the leakage has been found. He must be in a position to recommend a better and a cheaper way of doing the particular operation that is costing too much. When these ideas are carried out in the plans for new mills, a much lower cost production can be assured. The cost engineer must always be in a position to actually back up his findings as well as his recommendations with definite, concrete and convincing reasons and facts. His reports will be examined by many other engineers and operators who will ultimately be drawn into the final discussion of such cases. Hence he must know whereof he speaks. His analysis of conditions under question must be clear and complete.

In the steel mills and in other factories we are confronted every day with questions like these: What will be the cost of additional power necessary to raise the speed of a blower, or a mill table, or a compressor or some other machine? Will the increased output merit the increased cost? Or questions like these: What will it cost to add a number of cars to the present mine haulage, and is the present equipment for hoisting of sufficient capacity to handle the larger number of cars? If it is not large enough, would the increased production under the new condition merit the purchase, operation and maintenance of an entirely new unit? Or such questions as these: What will it cost and how shall we proceed to correct power factor conditions in an electrically operated plant? And what saving could be expected if such a scheme were properly put into operation? Sometimes it is required to determine the exact cost of each individual operation in a particular process and to find out if some operations could be combined, or reduced or changed in some way that might insure lower production cost in the end.

Such questions as those outlined above and many more of their kind are ever before the cost engineers who are engaged in the very interesting task of reducing operating cost. Such questions are the interesting things in the engineering profession which keep the engineer abreast of the times and alert to his duty. If perchance he meets with success in any such undertaking, and he surely will if he perseveres, it will serve as a new incentive to further efforts in the same or other fields.

The work of the cost engineer is never done. His opportunity is as wide and as varied as the manufacturing industry itself. The sky is the limit. His technical or practical education together with his experience, backed up by a good store of common sense will enable him to serve well. He must also have enough personality of a pleasing and helping nature to instill his ideas into the every day practice of the men who actually perform the operations. In this way the work of the cost engineer will ever grow, and new fields will open up to him with the progress of the industry he serves.

*Engineer of Tests, Tenn. Coal, Iron & R. R. Co., Birmingham, Ala.

RADICAL IMPROVEMENTS ON ROLLING MILLS

By J. H. VAN CAMPEN*

THE improvements made in the past few years to electrical and mechanical equipment used in the manufacture of steel products have been so rapid that it has been a difficult problem for managers, operators, and engineers to keep abreast of these developments.

*Chief Engr., E. W. Bliss Co., Salem, Ohio.

One of the most radical and rapid developments in this industry has been the application of anti-friction bearings to a large number of main roll necks of rolling mills. Bearings of this type have been applied in one form or another in the past, to roll necks without any appreciable degree of success. The mill operators had heretofore viewed this equipment as being unreliable for this particular service, but with the keen competition in the steel industry, and the desire of every steel plant manager to reduce operating costs to a minimum, combined with the improvements made in design and manufacture of anti-friction bearings, the bearing manufacturers have developed their product to such a point that the anti-friction bearings appear to be demonstrating to be perfectly reliable for this particular service.

The anti-friction bearing applications made during the past year have been applied principally to hot and cold strip mills of both the Cluster and the Four-High types, on which the limitations have been such as to permit the installation of this equipment to carry the extremely heavy loads such as come upon roll necks of mills of this type.

One Two-High and Three-High mills, such as rod, merchant and structural mills, the developments have not been so rapid, mainly due to the limitations for installing the necessary bearing capacity. There is no doubt that with the experience gained on present installations that satisfactory anti-friction bearing applications will be made in the future to mills of this type.

As to the benefits derived from the use of anti-friction bearings on roll necks, it is a well known fact that a very large percentage of the power used in driving rolling mills is wasted in the form of roll neck friction. On various applications made during the past year with anti-friction bearings on main roll necks, comparative power tests have been made in order to determine more accurately the power saved in rolling mills equipped with anti-friction bearings over mills equipped with plain bearings. The results of some of these tests have shown a net power saving, which considers both the rolling load and friction load, from 25% to 45%. When taking into consideration the large units necessary in driving rolling mills, this would mean a considerable saving in operating costs, in a very short period of time.

In the installation of new mills where the design can be made to incorporate anti-friction bearings on the main roll necks, a considerable saving can be made in the original investment by the installation of smaller driving units. Taking into consideration a smaller power requirement necessary with the use of anti-friction bearings, we have not only the economies gained in power, but there is also considerable saving due to maintenance.

With the use of such equipment it is possible to roll more accurate materials on mills, as there is a very small amount of wear in anti-friction bearings as to what there is on plain bearings.

From the various papers which will be read before the Society's Annual Convention, it is hoped that there will be a considerable amount of information brough to light as to the various applications which have been made, as the indications point very strongly towards a wide adoption of anti-friction bearings for the main roll necks of rolling mills where the limitations are such as to allow the installation of bearings of this type with sufficient capacity to carry the loads coming upon the mills.

WHAT PRICE CERTITUDE?

By D. M. PETTY*

CERTITUDE may be defined as "freedom from doubt."

Should the Electrical Engineer in the Steel Industry ever be free from "Doubt?" The writer does not think so. This conclusion has been reached after considering many of the blessings that have accrued to mankind on account of the "Doubters."

Somebody doubted the well known fact (well known in 1890) that a steam engine was the best drive for a Blooming Mill and today it is a well known fact that a D.C. motor is the best drive. If no one ever doubts this fact then a D.C. motor will remain the best drive, but the writer ventures to suggest that some day, some other electrical device will prove to be better.

Most Steel Mill Engineers believe that compound wound generators and rotary converters are the best converting apparatus through which our D.C. motors must be supplied with power. The writer as well as a few others doubt this. We see no reason why a shunt wound generator or rotary converter is not a better unit.

Never be afraid to question **"the accepted practice"** of doing anything. Eventually a better way will be found. It might just as well be you as some one else to upset the apple cart. It is better for a better way to be found today than tomorrow.

Do you believe that the maximum speed in R.P.M. of a two pole induction motor is frequency in cycles per second multiplied by sixty? The writer doubts it, why can't it be twice this value and thereby give us a respectable speed for pumps when 25 cycles is our Plant frequency?

Do you believe we need the existing multiplicity of sizes in carbon brushes in order to successfully design and operate commutator motors? The writer doubts if we need over 14 sizes of carbon brushes. The writer, however, has no doubt in his mind as to the proper policy for the Association of Iron & Steel Electrical Engineers to follow in this or any other matter where standardization offers a reduction of 50% in the present operating bill.

The writer is sure that every Steel Plant Manager as well as every Steel Company President will endorse any action of the Association of Iron & Steel Electrical Engineers tending to support the movement now on foot to standardize carbon brush sizes because such a move will cut the carbon brush bill of the Steel Industry in half and this bill the writer finds upon investigation, is not a small but a large item.

The writer feels that unless the Association officially gives this movement its full support, not only in the Committee work that must be done, but also in the general publicity involved in informing the operating engineer as to the true meaning of standardization in this instance, the Association will have fallen short of fulfilling its obligation to the Steel Industry.

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*Elec. Supt., Bethlehem Steel Co., Bethlehem, Pa.

The writer hopes that all those who are in doubt as to the feelings of the Steel Plant Executives in this matter will put the matter before their superiors in this way: "Do you favor a movement to cut the carbon brush bill of operating motors and generators 50%?" What price certitude? Stagnation! is the answer. The more accepted a practice becomes, the more dangerous it is. There is nothing being done today as good as it will be done tomorrow if we are **Doubters.**

THE REHABILITATION OF STEEL PLANTS

By A. R. REICHERT*

IN the past history of Steel Plants it seemed to be the practice that as long as a piece of machinery would run (no matter how antiquated it might be) and produce a certain limited amount, there was no need of replacing it.

Now the trend of times have changed, for with keen competition and rigid specification of steel, it is almost compulsory to modernize the Steel Plant.

This is a competitive age, competition together with the location of the market are governing factors in the selling of the product. Competition fixes the price of the raw grades of steel and steel products. The more efficient plants set the selling price, regardless of agreements and the less efficient plants must sell at the price thus set.

The ultimate profit that is left for the stockholder upon each ton of steel produced is the difference between the cost of production and the price received for the steel.

Each plant can incorporate greatly in its product and produce steel at a cost approximately the same as any other plant. It is simply a question of proper, efficient and dependable apparatus, added to predetermined manufacturing methods which have been determined by past experience.

The cost of producing steel is based upon three principal factors:

1—Cost of raw materials delivered to the furnaces.

2—Cost of manufacturing.

3—Overhead, which includes the cost of keeping the equipment in a given state of repair and operating efficiency.

This all means rehabilitation of the old but well established plant, the abandoning of those portions which are slow in production and costly in their upkeep and replacing with modern equipment.

A study must be made of each branch of the manufacturing process with its attending apparatus and its effect upon the cost of production. Comparison must be made with what is considered the best established practice and with the possibility of its further improvement. The things we are seeking are lower manufacturing costs, quantity production, quality in the product, dependability and continuity of service.

It is difficult at times to collect the necessary data in advance to prove the fact that in most all cases the proper, modern machinery installed will in time more than offset the cost by increased production and lower operating and maintenance costs.

*Elec. Supt., The Bourne Fuller Co., Cleveland, O.

In the successful manufacturing practices of today the cost of upkeep on equipment must be reduced to a fraction of that which was permissible in the past.

When purchasing equipment there are a number of requirements to be taken into consideration, such as the longevity of the apparatus and its wearing parts, freedom from more than casual inspection and adjustment together with quick replacement and safety added to its ability to function continuously in the manufacturing process, are the deciding factors.

At the present time the outstanding improvement in Steel Plants is the replacing of the Steam Drive, for rolling steel, with the Electric Drive. In this case the cost of the equipment and the installation is quite an item and also it necessitates the suspension of all operation in most departments throughout the plant. This means orders for steel are either refused or delayed for some time. Even though the company may be sold on the Electric Drive idea it may not be convenient to stop operations during normal times. But in spite of these facts many plants are now rolling steel electrically and many others are contemplating the change.

Modern equipment installed in one part of the plant soon shows up weak points in some other department, as one operation bears some relation to every other operation in the steel plant. Therefore with the Electric Drive installation, the Table Drives, Cranes, Furnaces, etc., must also be brought up to the same standard of efficiency.

Some of this can be accomplished by the purchase of new motors equipped with roller bearings or buying the bearings and machining the housings of the old motors to fit. This type of bearing requires very little lubrication or attention and in most cases reduces motor troubles considerably. With sleeve type bearings used on motors under severe operating conditions it is necessary to lubricate with oil every day and in some cases every few hours. After the installation of roller bearings under the same working conditions, greasing once per month is ample lubrication.

Crane efficiency is greatly increased by the use of Roller Bearing Motors, modern control equipment and rigid inspection at regular intervals to avoid all delays possible. Regular inspection and repair of minor troubles bring good returns, not only on Cranes but on all machinery throughout the plant. Troubles develop (which may seem minor at the time) that may cause a breakdown later if neglected. For instance the majority of direct current motor breakdowns are due directly to a grounded commutator, which can be avoided if the "V" Ring is kept clean and well insulated. This is just one instance of trouble that may be eliminated by frequent inspection.

By reducing the repair labor upon a piece of machinery we thus release a man for the attention of other equipment for a period equivalent to the saving. This is one of the two or three fundamentals that from the basis of the present production study, the reduction in operating and repair labor together with the reduction of repair materials are the big factors.

The cost of upkeep of equipment in past practice constitutes the premium on an enormous mortgage

on the resources of the concern. It had all to come out of the profits. Thus upkeep cost formed the interest on an enormous investment that was non-existent. Now if an amount of money is invested in certain new equipment that will eliminate part of the upkeep cost, we are justified in so doing. Suppose a saving in upkeep expenditure, including labor, can be effected by installing new apparatus, then we would be justified in spending at least six times the momentary savings.

STANDARDIZATION OF CONTROL DIAGRAMS

By O. C. CALLOW*

THE several editorials appearing in recent publications of The Iron & Steel Engineer on "We are standardized on" are of interest since they tend to show that even standardization is no exception to the rule that there are two sides to every question. Even though we may standardize on a certain make of equipment there is always a certain amount of "foreign" makes creeping in and a certain amount of old equipment which is doing its work well and therefore must be retained. This condition applies to Controllers probably more than any class of electrical equipment. We may standardize on a certain make and may have a large number of this make but there are very few plants which do not have quite a number of other makes of controllers scattered around the mills on more or less important equipment.

The writer is not advocating the standardization of Control but does believe that there is a long-felt want for a standardization of Control Diagrams particularly covering Mill and Crane Magnetic Controllers.

Let us take a crane hoist panel and compare the diagrams of several of the companies who built this type of equipment. We find that some show a front view of the panel while others show the rear view. The system of numbering the wiring varies in many ways. Some show the sequence of contactors and scheme of main connection while others make up a separate diagram showing the line diagram. The resistance numbering varies as does the way of illustrating relays, interlocks and the contactors themselves.

Some of the larger steel plants who maintain a drafting and engineering department have already made up their own standardized diagrams on which they have included as well as the main diagram, the scheme of main connections, the sequence of contactors, the line diagram, the resistor data and in some cases even the contactor coil data. In a plant using many hundred magnetic controllers, the cost of making these diagrams is considerable even although many of the panels are duplicates. Furthermore in a small plant without any facilities for the work, it is almost impossible to get this redrawing of diagrams taken care of.

Since the manufacturer has to draw up a diagram for each different control panel he supplies, the expense of making these diagrams standard in regard to symbols and general arrangement and to include all the necessary information would be small indeed and would save the duplication of this work and the expense involved.

Operation delays can be reduced if the maintenance electrician is entirely familiar with the control for which he is responsible. If he has ready access to the blue-prints of these panels and is taught to study same and use them in a case of trouble, valuable time may often be saved.

However, if we expect this man to study his diagrams we must make them as simple as possible for him, show all the information on one sheet and put it in such a form that he does not have to be a technical graduate and have a pencil and paper to trace out a circuit. Once he has become familiar with a certain set of symbols and numbers for one control, he will have little difficulty in understanding others of a different manufacture if the diagrams are standardized.

It would seem that after it has been found possible to standardize a line of mill type motors, it should be an easy matter to standardize Control Diagrams for steel mill and crane magnetic controllers.

*Elec. Supt., The Trumbull Cliffs Furnace Co., Warren, O.

SUCCESSFUL CONVENTIONS AND EXPOSITIONS

By J. F. KELLY*

What constitutes a successful Convention and Exposition? Not mere attendance or representation by any means, but an active personal interest in every business, technical, and social session that is being held by your Association; a visit to each and every booth at the Exposition, your co-operation with each and every program that has been prepared for you, for your education, and entertainment.

A Convention and Exposition of the Association of Iron and Steel Electrical Engineers is a post graduate course in the Engineering Branches of the Iron and Steel Industry.

You have an opportunity to listen to the brightest and keenest minds in that industry. This does not mean merely the authors of the papers, but the best trained minds of the Operating Superintendents and Engineers of the Steel Industry, who discuss the problems of that industry.

You are also permitted the privilege of seeing and examining at first hand the inventions, practices and developments that have been made in the apparatus for the past year, which is used in the Iron and Steel Industry. This Exposition alone is, in itself, a college of learning.

One other leading feature that is often overlooked is the fact that you are permitted to make and form a personal, human contact at your Annual Convention with the Superintendents and Engineers who have to do with the operation of steel plants from practically every Steel Center in the United States. This contact enables you to exchange ideas and problems that have to do with your daily practices at your plant.

Every member of the A. I. & S. E. E. should take advantage of the post graduate course prepared by the Association in their Twenty-third Annual Convention and Exposition.

*Managing Director, Iron & Steel Exposition.

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The Flat Suspended Open Hearth Roof*

By A. L. FOELL†

THE function of roofs on furnaces in general is to provide complete enclosure between side walls for both combustion chambers and the heating chambers, or the chambers in which certain operations in the presence of higher temperatures are performed. This, of course, a furnace roof must do in order to prevent loss of heat and in order to make possible the conditions by which heating and other furnace operations can be carried on. Along with the other parts of a furnace, the roof must contribute toward making possible the conditions required for good combustion, especially in furnaces where fuels are used to create higher temperatures. The roof, is generally the most important factor in the distribution of heat and must, because of its position in the furnace, cause a uniform radiation of heat over the entire area of the medium to be treated in the furnace. It must further serve to confine the products of combustion and keep them in contact with the material to be heated or to be given certain treatments under temperature.

An ideal furnace roof would be, one through which radiation loss is eliminated; one which would have an infinitely long life requiring no repairs; one which would have neither expansion nor contraction and in which spalling and consequent leakage is entirely eliminated; one which would not introduce stresses or strains in the remainder of the furnace structures tending to weaken them; one which would withstand an infinite temperature and resist the errosive actions of the products of combustion and one which would finally withstand the mechanical abuses which furnace operatives so frequently impose upon a roof. The problem of furnace roof design, therefore, is to approach these features as closely as possible and these are matters with which furnace builders and operators have for years contended.

The conventional sprung arched roof, as applied to open hearth and other furnaces, owes its development and wide use to the fact that up to within recent years no other practical and no other more simple method for constructing a furnace roof was available. For ordinary purposes not related to furnace roof construction arches of masonry were commonly used in the earlier days for spanning across gaps between abutments even where other structures might have been used for the same purpose. This, however, was not the case in a furnace roof construction since the roof portion, exposed to temperature on the inside, had to be of a refractory material. Consequently roofs were and still are built by spanning the gap between the side walls of furnaces with an arch of refractory material and supporting it on abutments, commonly called skewbacks, which are held rigidly in place by the furnace binding or buckstays and in turn by tie rods. A number of variations, have from time to time, been made in the construction of sprung arches in which the aims have primarily been to lengthen the life of roofs of this type of construction. Most notable among these is the so called ribbed arch, in which every second or third course in the roof of a certain thickness is laid up of a brick of greater depth. The developments have, however, been limited and the attempts at improvement have met with indifferent success.

A marked departure from the sprung arched roof construction was made about fifteen years ago on boilers and reheating furnaces in the form of a flat suspended roof. This type of roof has been almost universally adopted in boiler work and very frequently applied on reheating furnaces principally because the general tendency has been to build furnaces of greater widths in which the difficulties ordinarily suspended roofs on these types of furnaces and the economies which they have shown, point to the advisability of further considering their application to furnaces on which roofs are a serious factor due to construction difficulties and wherein they are subjected to severe service. Having in mind the success that has been experienced with flat suspended roofs on boiler settings and certain reheating furnaces, the operating department of Donner Steel Company, Inc., more than a year ago, carefully considered the application of the suspended type of roof, on one of their open hearth furnaces.

Among the ten open hearth furnaces in operation at this plant there are two tilting furnaces which were converted into stationary furnaces about ten years ago. These two furnaces have an entirely rigid binding with solid structural steel cross-members between the front and back wall buckstays. These solid cross-members do not permit adjustment of the binding to suit the expansion and contraction of the sprung arch as can be done on furnaces equipped with tie rods. The inability to adjust the binding was considered, in part, the reason for the low roof life on these furnaces when using sprung roofs. To alter the binding and to install tie rods would have required a considerable expenditure of money and might have required the rebuilding of the entire furnace binding above the charging floor. It was, therefore, proposed to make a trial installation of a suspended flat roof as a solution to the problem and as a means of increasing the roof life.

In considering the application of the suspended flat roof, however, we were confronted with a number of objections to its use. We were very much in doubt as to whether or not a flat roof might not have a detrimental influence on the operation of the furnace and just where to place the roof with reference to the crown of the old sprung arch. If the flat roof were placed at any point above the under side of the skewback it was natural to assume that we might have difficulty with the front and back walls which might result in greater maintenance costs on them. A further objection to the suspended roof, as against the sprung arch, lies in the fact that the former represents a greater initial expense. The possibility of increased roof life, however, with the suspended type of roof seemed very probable for two reasons—first, in that the furnace, on which it was to be tried, was not equipped with tie rods which are essential to the sprung roof and not required with the suspended roof, and second, in that the pressure in the refractory roof material

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is practically eliminated in the suspended roof while of considerable magnitude in the sprung arch. These two factors were considered the important features which would greatly contribute toward increasing the life of the refractory. It was also expected that the flat roof would effect a more even distribution of heat over the entire bath through parallel lines of radiation and, thereby, result in the possibility of securing faster time on heats. While it was not anticipated, the possibility of increasing the life of

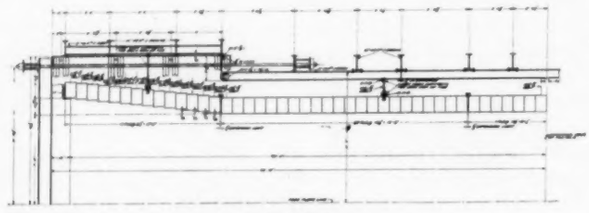

FIG. 1.

the front and back walls was to a certain extent expected by virtue of relieving all pressure on these walls from the roof and because of the increased furnace volume. Another important advantage, incident to the suspended roof, is the elimination of all possibility of having a roof fall in at any time during a heat and with proper care the elimination of all necessity for shutting down the furnace during a heat for the purpose of rebuilding the roof, as is so often the case with the sprung arch. In putting on a new roof the human element is greatly eliminated since the suspended roof is not so dependent upon the skill of brickmasons as is the sprung arched roof and further does not require the placing of centers for the purpose of laying up the brick. However, in spite of the many advantages

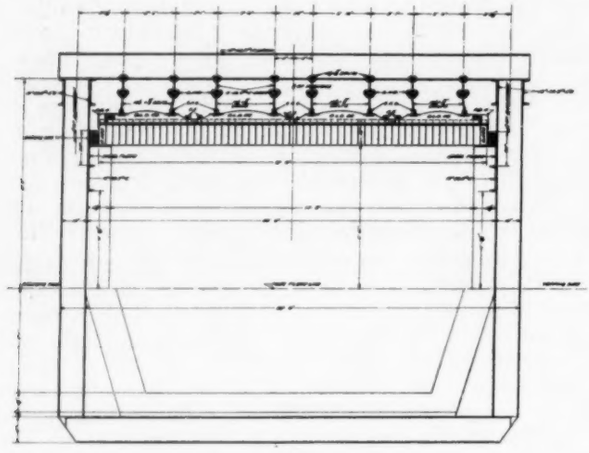

FIG. 2.

which could be forseen in favor of the flat suspended roof the prevailing atmosphere of conservatism, together with objections by the open hearth department in taking too radical a step, led us to install a suspended arched roof on number two furnace, which was formerly one of the tilters and which is being operated as a stationary furnace.

The results on this suspended arched roof as compared to previous performances were very gratifying. In spite of the fact that this roof was only of 12" tile having 9" of refractory under the hanger 245 heats were taken out of the furnace when it became necessary to take the furnace off for repairs and improvements. The roof required some patching and might possibly have been left on the furnace for 75 to 100 more heats. Instead of patching it, however, we decided to replace it and try out a flat suspended roof with a deeper tile.

Number two open hearth furnace is 74'-8" long between insides of end walls and 17'-9" wide between the interior surfaces of 13½" thick front and back walls. This furnace is fired with coke oven gas and tar as a fuel. The under side of the flat roof over 50'-10" of hearth is located 7'-0" above the fore plate line. The roof is flat across the furnace at all points in its length, and at the end walls is 15¾" higher than the flat portion over the bath. From each end wall the portions over the ports slope through a distance of 11'-11" until they meet with the hearth portion. See Fig. 1.

Silica tile 15"x10½"x4" were used throughout in which 12" of tile is below the hangers and the 4" face was placed across the furnace. The hearth portion required 3306 tile of which 3074 are exposed

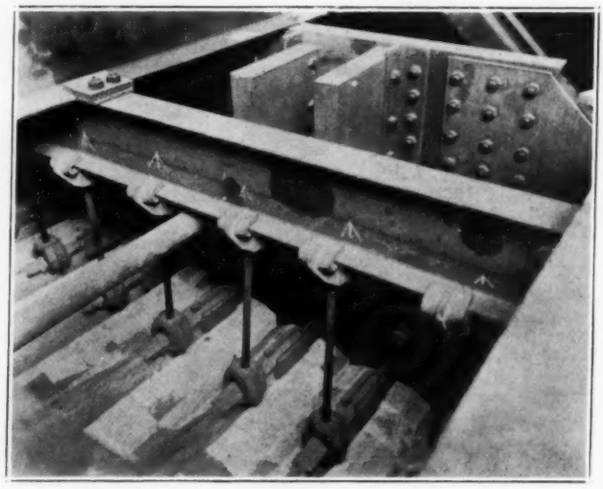

FIG. 3.

to the products of combustion. Both sloping ends required 1596 tile of which slightly less than 1500 are exposed to the flame. The tile are suspended in groups of 15 by castings arranged in rows across the furnace with four castings to the row. Each casting is carried by two hanger rods, ¾", which suspend it from 8" I Beams running longitudinally over the furnace. There are eight of these beams approximately 2'-6" apart. The 8" longitudinal beams are carried by eighteen 15" I Beams running across the furnace. These are carried on the furnace buckstays and binding members at each end. Every tile in the entire roof is suspended and carried by the steel structure above. Four ¾" expansion joints are provided across the furnace approximately equally spaced between the end walls. These joints are sealed by a row of brick laid above the joint and on the adjacent tile. An expansion space is also provided between the front, back and end walls and the under side of the roof at these points and is sealed with chrome ore. See Fig. 2.

The time required to install the flat roof, totaling 4902 tile was approximately 100 mason hours or

one mason's time for 100 hours, not including time for mason helpers. A flat suspended roof has however since been placed on No. 10 furnace, which is somewhat smaller, and which required a total of 3456 tile, in 45 mason hours. Based on the time required to tile the roof on No. 10 furnace the larger No. 2 furnace should in the future be retiled in 64 mason hours or less. Improvements in the time required to place the tile will no doubt be possible after the brick masons become more familiar with the matter of handling the roof tile and after they have had an opportunity to acquaint themselves with the possible short cuts. See Figs. 3-4-5.

Up until April 22, 1927, when No. 2 furnace was last taken off, the total number of heats taken out

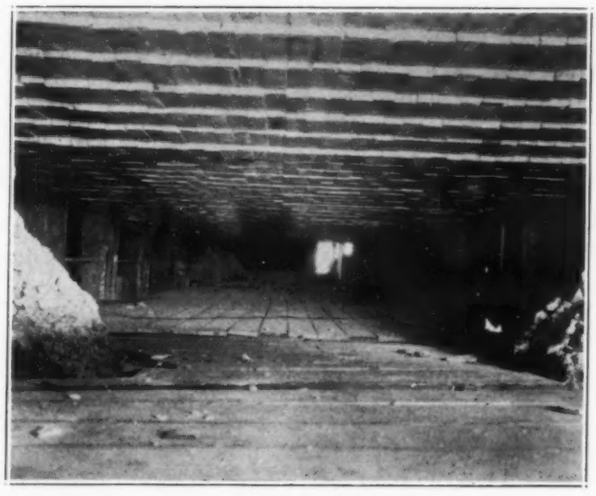

FIG. 4.

under the flat suspended roof was 420 heats averaging slightly over 100 tons per heat. A new hearth bottom was burned in when the furnace was put in operation with this roof in place, which we customarily consider as equivalent to 25 heats, which on this basis would bring the total number of heats up to 445. This compares with an average roof life on this furnace of 132 heats which life is abnormally low for reasons explained before and compares very favorably with an average of about 200 heats for the entire shop. The average for the entire shop, it is well to point out here, is low largely for the reason that both No. 1 and No. 2 furnaces contribute their share in reducing the average for the entire shop.

During the 445 heats on the flat suspended roof, approximately 1900 repair tile were used in patching. The total delay, on account of roof repairs, was 38 hours and 20 minutes. Mention has not been made before of the features provided in the construction of this roof to facilitate the matter of making repairs. For every 12 or 14 tile suspended in any row on a single casting 3 or 4 tile can be conveniently and separately removed so that a space is provided to enter and slip onto the casting new or repair tile to replace the tile which have either dropped out or have been burned through. After any or all the tile on a single casting have been replaced the space occupied by the separately removable tile can either be replaced by new tile or by those previously removed.

Contrary to the general belief that the front and back walls would not stand up because of the additional height of these walls as required with the high flat roof, these have stood up longer than with the old type of sprung arch. This is no doubt surprising since the front and back walls have actually been heightened 1'-10" over their previous height. The front and back walls opposite the hearth were 5'-2" in height from the fore plate line to the under side of the skewbacks on the sprung arch while this height now is 7'-0". The approximate number of heats on front and back walls with the sprung arch roof was normally 80 and 67 respectively. We are now getting the same number of heats on back walls as on front walls on No. 2 furnace equipped with the flat roof. The first set of walls with the new type of roof lasted 167 heats to which should be added an equivalent of 25 heats for burning in the bottom or a total of 192 heats. The second set of walls stood up against 137 heats, while the third front and back walls registered 116 heats when the furnace was taken off on April 22. It can safely be said that the flat roof on this furnace has not impared the operation of the furnace in any way nor has it had a detrimental effect on any part of the furnace structure. We have noted an improvement of 19 minutes on the average time of heats since the flat arch was installed, but this improvement is not attributed entirely to the roof construction. In explanation of this I might say that a number of other improvements were made simultaneously with

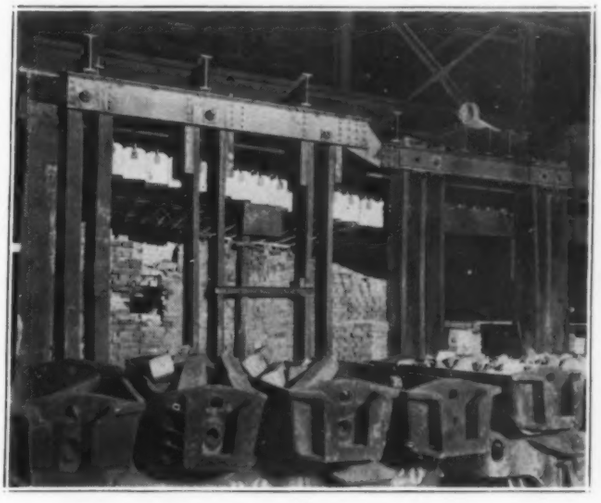

FIG. 5.

the application of the new roof which undoubtedly were most responsible in speeding up the furnace. The flat roof, however, has had no tendency to retard the furnace and if anything has helped somewhat to decrease the time of heats.

The possibilities with the flat roof have, with our attempts, not been exhausted. We feel that a great deal is to be learned by changing the height of the roof with respect to its position above the fore plate line. In placing the under side of the flat roof 7 feet above the fore plate we have without doubt started with a maximum dimension. In the future our attention will be concentrated on determining the height most suited to obtain maximum furnace production which, of course, will also in-

volve port changes in order to secure the most favorable conditions for proper combustion. With this accomplished it will, we believe, naturally follow that the life of the roof will be increased particularly with reference to the number of heats or the total number of tons produced. Our experiments in the matter of lowering the roof will undoubtedly extend over quite a period of time since considerable caution will be required in determining the proper position. Each step will be taken gradually and I believe will not be over two or three inches at a time. I believe that the conditions for hot patching the flat suspended roof particularly as installed on our furnace are more favorable than they are on the sprung arch. This for the reason that the supporting steel work offers a convenient means for placing temporary scaffolds and greatly facilitates the matter of handling material to the spot to be patched. This structure also offers an apportunity for the brick mason to position himself advantageously in making a repair and helps him in placing the required protection for himself against heat. We have not reached the minimum in time of making hot patches as yet. Further possibilities exist in reducing the time required for this work especially as our men become more familiar with the procedure. In making patches we have already discovered a way in which to economize on the cost of tile. A new roof is layed up of 15" thick tile having 12" of depth under the hanger. When this roof requires patching the depth of tile under the hanger is considerably less. We are using a 12" tile with a depth of 9" under the hanger, instead of using full 15" tile for repairs, and have lately made further reduction by using a 9" tile with 6" under the hanger.

Important among the considerations applying to open hearth furnace roofs and their construction is the matter of how many heats it can withstand before requiring replacement. The suspended roof can never entirely fall in at one time such as is the case with the sprung arch but still must have a very definite period of life. The question has very properly been raised several times as to how to determine just when the suspended roof on our No. 2 furnace is to come off for complete replacement. From all indications the roof will, with ordinary care, never require complete replacement at one time since certain portions of the roof, from our present observations, are going to outlast other portions for a considerable length of time. However to give some indication as to the life that might reasonably be expected, on the average, I might say that we feel that 500 heats will not be impossible. The results so far on our No. 2 furnace have been sufficiently encouraging to prompt us in installing a suspended arched roof on our No. 1 furnace and a suspended flat roof on our No. 10 furnace. Two additional flat roofs are now on order to be installed on remaining furnaces during this year.

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*Fifteen Years of Steel Mill Illumination—What Change?**

By WARD HARRISON†

IN the years 1911, 1912 and 1913 the writer was privileged to present before this Association a series of papers dealing with lighting practice in the steel industry. Since then but one paper on the subject has appeared on an annual convention program—it seems particularly fitting, therefore, that in taking up the subject again at this meeting we should survey briefly what progress, if any, has been made and what changes have come about during the intervening period of fifteen years.

The one general comment that can safely be made about almost all things whether they be shoes, houses, drugs, labor, food, building materials, or railroad fares is that they seem to cost about double what they did fifteen years ago. To be more exact, the statistics of the U. S. Department of Labor show that the average costs of all commodities which go to make up the total expenses of an individual or a corporation are now 68% in excess of what they were in 1914.

If we assume this increase is a basic figure, then we might say that those industries, in which the price increase of the products manufactured has been less than 68%, have improved their efficiency by an amount more than the average for the country as a whole, and those in which the cost increase has been greater than 68% are, other things being equal, less efficient than the average. It is of interest to you men in the steel industry, and you are to be complimented on the fact that the composite price of finished steel products has increased but 59% since 1914. This price based upon the Iron Age review of market quotations shown in Chart I includes prices on steel bars, beams, tank plates, plain wire, open hearth rails, black pipe, and black sheets. Measured by the above criterion, the relative efficiency of the steel industry over the fifteen year period is from 7 to 8% ahead of the average.

Let us now consider what has happened in the artificial lighting field in the same period. Fifteen years ago we were, as you will recall, just at the close of an era during which the standard illuminant for steel mills was the 250 volt, 3 ampere direct current enclosing carbon arc lamp and at the beginning of the year in which the Mazda lamp became the almost universal illuminant.

At that time Mazda lamp manufacture was limited to the "B" or vacuum type of lamp, in the larger sizes of which an efficiency of from 8 to 9 lumens of light per watt were obtained. It was

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†Director of Illumination, National Lamp Works of G. E. Co., Cleveland, Ohio.

during this time too that Dr. Langmuir in the General Electric Research Laboratories, performed his first experiments on gas-filled lamps. Without going into too much detail, it may suffice to say that in the fifteen years since those first experiments were conducted, the efficiency of light production in the same sizes of lamps has been approximately doubled. In other words, we now obtain from 15 to 20 lumens per watt as against the 8 to 9 referred to above. The progress in lamp making has not, however, been confined only to the improved efficiency at which the lamps operate but, hand in

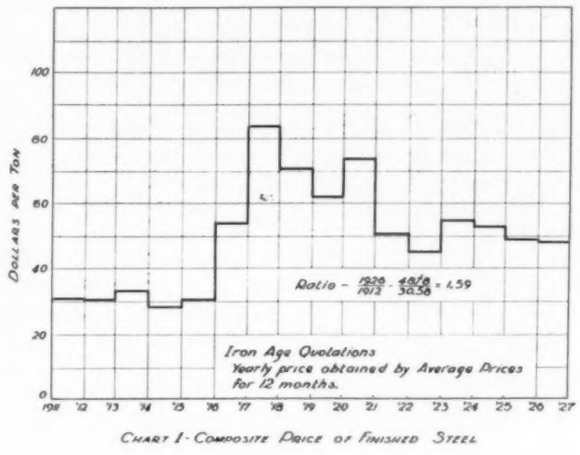

CHART I - COMPOSITE PRICE OF FINISHED STEEL

Chart 1

hand with the increased light output, have also come modern methods of manufacture which have resulted in an enormous decrease in the cost to the user. An idea of this progress may be gained by referring to Chart II which gives graphically the efficiency and the lowering in price of the 150 watt size of lamp which is very closely typical of the line as a whole. During the fifteen year interval between 1912 and 1927, it will be noted that the light output of this lamp has substantially doubled, and its list price has decreased from $2 to 60 cents; as far as the lamp itself is concerned, its cost per unit of light delivered has gone down in the ratio of nearly 6 to 1 during the time when other commodities have increased by 68%.

In the total cost of light, the cost of electrical energy is of course a far larger item than the cost of the lamps themselves. In order to obtain for this paper a reliable basis on which to compare the costs of light and power in 1912 with the cost in 1927, figures have been obtained from nine plants located in five different cities representing the principal manufacturing districts of the iron and steel industry. The data obtained by this survey revealed the fact that there was on an average, combining those mills generating their own power and those purchasing their power, an increase of 28% in the cost of wholesale power.

Twenty-eight per cent is far below 68%, the general average increase in the cost of commodities, and it is evident that in the manufacture of power as well as of lamps, the electrical industry has set a remarkable standard of efficiency and economy. Just how this economy is reflected in the reduced cost of delivering light to the working area in a particular mill is clearly shown in Table I.

TABLE I

	1912		1926		
	250 v. DC Arc Lamp, 750 Watts	150 Watt 110 v. MAZDA	150 Watt MAZDA	200 Watt MAZDA	300 Watt MAZDA
Number of Lamps	16	80	80	80	80
Total Kilowatts	12	12	12	16	24
Average Ft.-Candles	1.15	5.25	9.	13.	21.
Operating Cost of Installation, 4,000 hrs. of burning	$852.80	$1108.00	$967.20	$1158.40	$1622.40

It will be noted from Columns 2 and 4 of this Table that for what it costs to operate 80—150 watt lamps in 1912, 80—200 watt lamps can be operated at the present time, and this in spite of a 28% increase in the cost of power. Meanwhile the value of steel products has gone up 59%. In 1912 it took 36 tons of steel to pay for the operation of the 150 watt Mazda installation. Today the sale of 36 tons of steel will more than pay for the operation of 80—300 watt Mazda lamps for a year; in other words the same 36 tons of steel will today buy 23 foot-candles of illumination, where in 1912 it purchased but 5.25 foot-condles. Once more, if the comparison be extended back to the arc lamp, it will be seen that the amount of steel required to purchase 1.15 foot-candles in 1912 will purchase substantially 18 foot-candles in 1927, an increase of 1 to 16. The moral of all this is that if steel mills could have and did have any light at all, say 1 foot-candle in the arc lamp era which preceded 1912, then 16 foot-candles is a reasonable and a comparable intensity

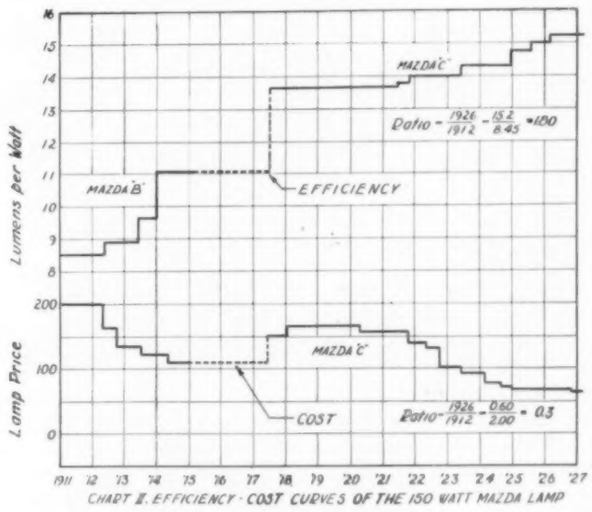

CHART II. EFFICIENCY - COST CURVES OF THE 150 WATT MAZDA LAMP

Chart 2

to consider today, and there is really no excuse whatever for any mill to be poorly lighted.

The deplorable part of it is that in the face of all this many of our mills are very badly lighted, and almost without exception they are on a decidedly lower basis than other progressive industries.

In addition to those already pointed out (lamp manufacturing and power generation) what are some of the other industries in this country which stand out as conspicuous exceptions to the general in-

crease of 68% in the cost of manufactured products? One of these is the motor car industry where the purchaser can actually buy for 86 cents as much as he could get for $1 in 1912. A second is the manufacturer of electrical apparatus and machinery. Records of the largest manufacturer in this field show that in spite of enormously increased wages, the net selling price of all its products is but 15% more than in 1912. Judged by the criterion previously referred to, the efficiency of these two industries is at least 50% higher than for the average of the country as a whole and 40% higher than for the steel industry. Is it not significant that these two are also the best lighted industries in America. One cannot of course assume this is proof that good

FIG. 1—An illumination of 20 foot candles is provided in this Press Room by 1000 watt Mazda lamps located on 20′ centers and mounted 40′ above the floor.

lighting is responsible for the increased efficiency, but at the very least it shows that in the opinion of the executives who guide two of the most progressive and important of our industries today, good lighting is worth its cost and will return a profit. A detail or two regarding the illumination of the motor car and electrical industries may not be without interest; for example, automobile bodies are as most of you know finished on rows of conveyor lines. Some of these lines are more than 1000 feet in length, and when the end of the line is reached the body is complete and ready for shipment. Formerly, daylight was considered as absolutely essential to body finishing, and only the space near the windows was really useful. Today there are perhaps six conveyor lines running lengthwise through a building, and artificial light is used almost exclusively. A standard equipment consists of a row of projectors placed on each side of the conveyor and spaced 5 feet apart lengthwise, each projector being equipped with 1—300 watt Mazda lamp and a suitable distributing lens designed to produce a uniform illumination of approximately 60 foot-candles over the side of the body. The energy consumption averages approximately 10 watts per square foot of floor area.

In Figure I is shown a press room in which 1000 watt Mazda lamps located on 20′x20′ centers and mounted 40 feet above the floor produce an average illumination in service of 20-foot-candles.

In the high bay areas in which the sheet metal is applied to the body frames the illumination is of a still higher order, being supplied by 1500 watt lamps 24 feet above the floor and located on approximately 20 foot centers. This installation furnishes approximately 45 foot-candles at an expenditure of about 4 watts per square foot. Where is this paralleled in the steel industry?

In the large shops and assembly rooms of the motor car factories the present standard of illumination is 300 watt lamps on 8 to 10 foot centers, providing illumination values from 20 to 30 foot-candles.

In the General Electric Co. Plants, the standard for installation has become a wiring layout which will supply 3 watts per square foot with a line drop from the panel board not exceeding 1½ volts (branch circuits will carry 5 watts per square foot at not greater than a 2½ volt drop). Lighting fixtures have also been standardized upon which will satisfactorily provide correspondingly high levels of illumination as mentioned above. Since 1921 substantially 75% of the total area of the General Electric Plants has been lighted in accordance with these standards.

Very extended investigations have been conducted from time to time for the purpose of evaluating the results of good lighting. These so-called Production-Intensity tests have been carried on with such thoroughness and care and in such a wide range of fields that there is no longer any question that light facilitates production. To summarize briefly; the more important tests conducted in diversified industries showed production increases ranging from 10 to 35% and averaging 15% when the average illumination was increased from 2 to 11 foot-candles. The average cost of these systems was only 2% of the payroll.

TABLE II

Operation	Average Foot-Candles With Old System	Average Foot-Candles With New System	Increase in Production With New System	Additional Lighting Cost in Percentage of Payroll
(a) Pulley Finishing	0.2	4.8	35%	5.0%
(b) Soft Metal Bearing Manufacturing	4.6	12.7	15	1.2
(c) Heavy Steel Machining	3.0	11.5	10	1.2
(d) Carburetor Assembly	2.1	12.3	12	0.9
(e) Plant Mfg. Electric, Gas, and Sad Irons	0.7 (4.0 at tool pt.)	13.5	12.2	2.5
(f) Semi-Automatic Buffing of Brass Shell Sockets	3.8	11.4	8.5	1.86
(g) Mfg. Piston Rings	1.2	18.0	25.8	2.0
(h) Letter Separating	3.6	8.0	4.4	0.6
(i) Inspecting Roller Bearing Parts	5.0	20.0	12.5	2.4
AVERAGE	2.69	12.47	15.04%	1.96%

(a) Pyott Foundry Company (tested by Commonwealth Edison Company); (b) Foote Brothers (tested by Commonwealth Edison Company); (c) Lee Loader Body Company (tested by Commonwealth Edison Company); (d) Stromberg Carburetor Company (tested by Commonwealth Edison Company); (e) Dover Mfg. Co. (tested by Engineering Dept., National Lamp Works of G. E. Co.); (f) General Electric Co., (tested by Engineers of G. E. Co.); (g) Detroit Piston Ring Co., (tested by Detroit Edison Company); (h) U. S. Post Office Dept., (tested by Office of Industrial Hygiene of the U. S. Public Health Service); (i) Timken Roller Bearing Co., (tested by Engineering Dept., National Lamp Works of G. E. Co.)

While these really remarkable results were shown in production increases, various other hardly less important factors were also developed by the tests. Briefly stated these include such items as improved quality of product, decreased spoilage, better supervision, greater order and neatness of plant, and last but by no means of least importance a reduction in accidents. Of all the phases of lighting there is perhaps none in which a more deeply significant point of view to the steel industry has been developed than in the matter of accident reduction. One of the greatest contributions that has been made in so far

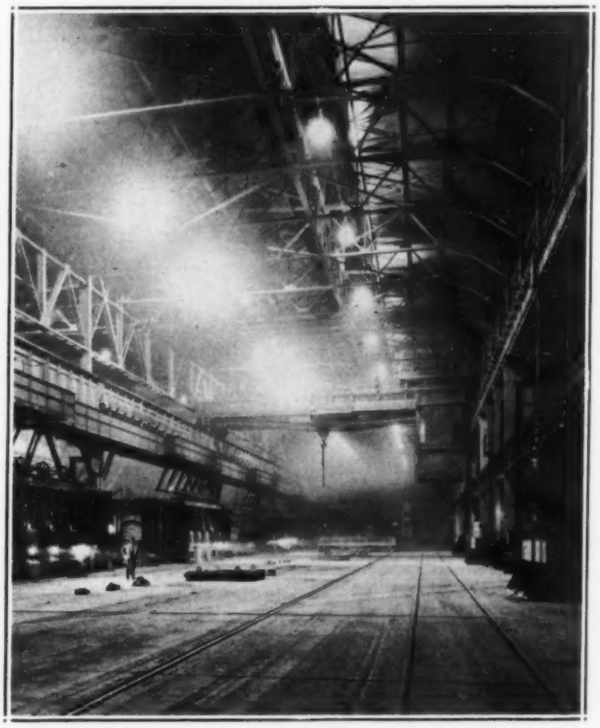

FIG. 2—Fifteen Hundred watt Mazda lamps spaced 40'x40' apart furnish an illumination of 9 foot candles for the open hearth building.

as the study of light and its bearing on accidents is concerned, is that of R. E. Simpson of the Travelers' Insurance Company. In his first survey ten years ago in which 90,000 accidents were investigated 25% were traceable in whole or in part to improper or inadequate lighting. Even with the very commendable Safety First movements in protecting dangerous and dark places and the improved illumination placed in effect since that time, Mr. Simpson's statistics indicate that there are still 15% of our industrial accidents which may be attributed to inadequate illumination. In 1924 this 15% of accidents resulted in a loss of wages to workmen of $80,000,000 and further entailed an expenditure for workmen's compensation of $90,000,000.

The September 1926 issue of the Iron and Steel Engineer printed a chart classifying some 300,000 accidents occurring on the properties of the U. S. Steel Corporation over a long period of time. Of particular interest in this connection is the statement that hand labor was responsible for 43.35% or nearly one-half of the accidents, the majority of which, as stated, cannot be controlled by the use of mechanical safety devices and appliances.

Carelessness, of course, is responsible for many accidents, but in about every mill there are unprotected machine parts in motion, obstacles in aisles and passage ways, and shadows which hide sharp cutting edges. In this field particularly there are extreme and blinding contrasts created by the incandescent metals which, unless alleviated, are too great for the eye to stand. All of these conditions invite injury. Mechanical safeguards reduce the possibilities of accident, but good vision itself is the most effective danger signal.

One might go on indefinitely to argue and bring home the advantages and economy of good illumination. Before you this is quite unnecessary, for I know that you are all well informed on this matter and appreciate its worth. In conclusion, however, I must remind you that the steel industry, in fact that this Association does not hold the place it once did as the recognized leader in the lighting field. During the years 1910 to 1914 inclusive there were on your Annual Convention programs 16 papers treating some phase of illumination. Since that time there has been practically no consideration of the subject by the Association as a whole, and as has already been shown today this industry is now far behind the practice of others in this field. Are you content that this condition should obtain?

APPENDIX
NOTES ON CURRENT LIGHTING PRACTICE

Steel mill operations are so diversified that space does not permit nor does it seem practical to present them here in a complete itemized list, with the foot-candle levels required in each case. Illumination levels have, therefore, been suggested for a number of typical operations and departments from which the lighting requirements of others may be gauged.

FIG. 3—One thousand watt Mazda lamps spaced 40'x40' apart furnish an illumination of 6 foot candles on these coaling beds.

RECOMMENDED LEVELS OF ILLUMINATION

2 to 4 Foot Candles

Rough Stock Rooms, Rough Packing, Cleaning, Rough Clay and Chemical Processes, Coal and Ash Hauling, Aisles, Passageways, Stairways, etc., Locker and Wash Rooms, etc.

6 to 8 Foot Candles

Soaking Pits, Reheating Furnaces, Rough Wood Work, Steel Fabrication, Steel Casting and Heavy Rolling, Plating, Grinding or Rolling Mills, Rough Bench and Machine Work, Rough Assembly, Rough Molding and Core Making, Engine, Transformer and

Switchboard Rooms, Rough Inspection, Shipping and Receiving.

10 to 20 Foot Candles

Fine Wood Working, Fine Stock Rooms, Automatic Steel Manufacturing Machines, Sheet Metal Works, Polishing, Burnishing, Painting, Fine Packing, Fine Bench and Machine Work, Automatic Machines, Light, Medium Inspecting, Fine Molding and Core Making, Fine Forging and Welding, Fine Assembly, Offices.

20 to 50 Foot Candles

Fine Inspecting and Sorting, Extra Fine Paint Finishes, Extra Fine Bench-Machine Work, Extra Fine Assembly, Drafting Room.

EQUIPMENT

The selection of the type of unit to be used necessitates a consideration of the location in which it is to be installed. In this connection it should be noted that for purposes of illumination design, steel mill structures may be divided into two general classes. First, there are those buildings in which the mounting height of lighting equipment is limited to 30′ or less. Second, there is a large number of buildings in which the presence of traveling cranes and other factors make necessary the locating of lighting equipment at extreme heights. It is to be expected then that the treatment required in the planning of lighting is different for the two cases.

Fortunately, those buildings coming under the first classification usually house departments and operations which are typical of most manufacturing establishments. For this reason, and because of the fact that lighting equipment for these ordinary industrial purposes has become so well standardized, it is only necessary when dealing with these buildings to select from a few types the particular one and size best adapted to the problem at hand. Porcelain enameled steel reflectors such as the RLM Standard Dome and the Glassteel Diffuser, and Dust-Proof units fulfill practically all the requirements of those buildings with the lower ceiling heights. When properly installed and equipped with lamps of a sufficient size to give the required intensity they make up a lighting system which embodies a degree of efficiency, freedom from glare and shadows, control, flexibility, ease of maintenance and other desirable features hitherto unknown in industry.

The high buildings of the second classification, on the other hand, require a more specialized treatment and probably the most important single factor in this connection is the selection of the lighting unit. The presence of traveling cranes in these buildings usually necessitates the placing of the equipment near the roof or, at least, the truss chords, and since these structures are usually of great height in comparison with their width, the use of reflectors which direct a great proportion of their light in the higher angles must result in a relatively low overall efficiency of the system. This condition is further aggravated in the steel industry by the fact that the walls of the buildings are almost invariably so dark as to eliminate any possibility of light being reflected by them. It is evident, therefore, that the requirements here would be best met by a unit which directs and confines the light of the lamp within small angles as measured from the vertical axis of the unit. In this way the light is delivered to the working plane with the least possible intervening losses.

Equipments which embody these characteristics in their design are available in metal and prismatic and mirrored glass types. It must be appreciated, however, that the greater degree of light control required and a limited application make them necessarily more expensive than the standard forms of porcelain enameled reflectors. On the other hand, the available maximum lamp sizes usually limit spacing distances to about 40′ so that the first cost of systems using this type of equipment is usually

FIG. 4—Rolling Mill illuminated by 1500 watt Mazda lamps located on 40′x40′ centers and mounted 40′ above the floor.

slightly higher than if the RLM or similar standard units were used. Good engineering, therefore, demands that in any particular case, this increment of cost be justified by higher efficiency or other accruing advantages.

LIGHTING SYSTEM DESIGN

Occasions sometimes arise in which it is necessary to install lighting units with special reference to the location of machines or to areas in which particular operations are regularly carried on. This gives rise to what is known as group lighting. There are also numerous cases in which exceptionally high intensities are required over very limited areas for which single low wattage units placed close to the work are usually most economical. In general, however, it may be stated that steel mill buildings can be satisfactorily lighted by means of overhead systems symmetrically laid out with respect to the building outlines or bay sizes. The location of outlets can thus be planned to produce uniform levels of the desired value throughout the entire area. This desired uniformity will be assured if outlet locations are determined according to the following "Mounting-Height-Spacing" relations.

When units are mounted above a traveling crane, it is usually desirable to use at least two rows parallel to the direction of crane travel. A staggered arrangement can be used if desired to eliminate the possibility of the crane's cutting off the light of more than one unit at a time and thus leaving an extended area in shadow.

TABLE III

SPACING OF OUTLETS

Ceiling Height (or Height In the Clear)	Spacing Between Outlets Maximum: Usual	Spacing Between Outlets Maximum: (For Units at Ceiling)	Spacing Between Outside Outlets and Wall Aisles or Work Benches Storage Next Desks, Etc.: To Wall	Spacing Between Outside Outlets and Wall Aisles or Work Benches Storage Next Desks, Etc.: Against Wall	Approximate Area per Outlet (At Usual Spacings)
(Feet)	(Feet)	*Not More Than		*Not More Than	(Square Feet)
8	7	7½	Usually	3	50-60
9	8	8		3	60-70
10	9	9	One-	3½	70-85
11	10	10½		3½	85-100
12	10-12	12	Half	3½-4	100-150
13	10-12	13		3½-4½	100-150
14	10-13	15	Actual	4-5	100-170
15	10-13	17		4-5	100-170
16	10-13	19	Spacing	4-6	100-170
18	10-20	21		4-6	100-400
20	18-24	24	Between	5-7	300-500
22	20-25	27		5-7	400-600
24	20-30	30		6-8	400-900
26	25-30	33	Units	8-9	600-900
30 & up	25-30	40		8-10	600-900

*In offices where it is definitely known that some form of indirect lighting will be used, the maximum spacing between outlets may be increased about two feet, and the distance of outlets from the wall may be increased by one foot.

When outlets have been properly installed to produce uniform lighting, the size lamp required to provide any desired level of illumination may be accurately determined by the use of tables and formulae which have been widely published elsewhere. For those cases in which the requirements of accuracy are less pronounced, the following table is

FIG. 5—Three hundred watt Mazda lamps in Glassteel Diffusers spaced 10'x11' apart mounted 11' above the floor furnish an illumination of 18 foot candles in this Tool Room.

presented in the hope that it will be of some assistance in the selection of the type of equipment to be used as well as in the general design of proposed installations.

For the sake of brevity and simplification only buildings of the "high bay" type and of at least 60 feet width have been considered, since they form such a large proportion of steel mill structures. It should be noted that in these buildings where the lighting equipment must be mounted at great heights, concentrating units always give higher foot candle values. Extreme conditions as to darkness of surroundings and unfavorable atmospheric conditions have been allowed for. An attempt has also been made to include some of the more commonly used and therefore the most typical spacings for various buildings. Here again the table is meant to serve simply as a convenient check on more accurate computations where the latter are necessary to a final and reliable solution of any given problem.

TABLE IV

Luminaire	Mounting Height of Units	Approximate Spacing	Approximate Area in Sq. Ft. per Outlet	Foot Candles in Service With Lamp Sizes as Indicated: 300	500	750	1000
	31-36	20x20	400	4.0	8.0	11.0	17.0
	31-36	20x30	600	2.5	5.5	7.5	11.0
RLM	31-36	30x30	900		3.5	5.0	7.5
	31-36	30x40	1200		2.5	4.0	5.5
Clear	31-36	40x40	1600			3.0	4.0
Lamp	37-50	30x30	900		3.0	5.0	7.0
	37-50	30x40	1200		2.5	3.5	5.0
	37-50	40x40	1600			2.5	4.0
	31-36	20x20	400	4.5	9.0	12.5	19.0
High Mounting	31-36	20x30	600	3.0	6.0	8.5	13.0
	31-36	30x30	900	2.0	4.0	5.5	8.5
Type Units	31-36	30x40	1200		3.0	4.5	6.5
	31-36	40x40	1600		2.0	3.5	4.5
(Concentrating)							
	37-50	30x30	900	2.0	4.0	6.0	8.5
Clear Lamp	37-50	30x40	1200		3.0	5.0	6.5
	37-50	40x40	1600		2.0	3.5	5.0

The dust and smoke present in mill buildings make frequent cleaning of lamps and reflectors a necessity in order to prevent ever increasing loss in the light output of the system. Any feasible method of facilitating maintenance is therefore worthy of careful consideration. Where the equipment cannot be easily reached it becomes necessary to make some special provision for maintenance work. In the case of units mounted near the roofs of high buildings it may be practical to erect a runway on the truss chords in such a position that rows of units can be reached and cleaned therefrom. If the maintenance man is to work from a crane the scheme indicated in Fig. 6 may be advantageously employed. A third plan, which has a wide application and numerous advantages, involves the use of devices by means of which the complete unit, lamp and reflector, is both disconnected from the circuit and lowered to the floor or some other position where the cleaning can be done with a firm footing. This not only reduces the accident hazard, but also enables the cleaner to do a more thorough job.

Even where units are, say, not more than 12 feet above the floor and therefore readily accessible from a step-ladder, the method of hanging shown in Fig. 6 or a modification thereof is often found to be of advantage. This is particularly true if cleaning otherwise causes production to be interrupted or subjects workmen or product to possible injury.

Where extreme conditions cause exceptionally rapid depreciation, protected lighting units may be resorted to. These consist of RLM Standard Domes or similar units, equipped with glass cover plates which help to prevent the accumulation of dust and dirt on the lamp and reflecting surfaces. Superficial cleaning of the glass cover at short intervals

with a thorough cleaning of the entire unit at longer periods maintains a higher efficiency of the system at a lower cost than is possible without their use.

Finally, it is advisable that provision be made in the initial installation for supplying higher levels of illumination which may be necessitated by changes in manufacturing operations, increased production, higher quality standards, etc. This may involve such factors as increased wiring capacity, larger reflectors, and in some cases the relocation of outlets.

EXTERIOR LIGHTING

There are three general types of lighting equipment suitable for the exterior lighting of steel plants: Enameled steel reflectors, giving either symmetrical or asymmetrical distribution, flood lighting units, and pendant street lighting equipment.

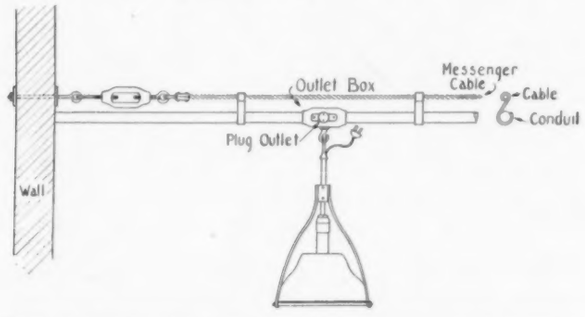

FIG. 6—Suggestion to facilitate easy maintenance

The enameled steel reflectors are particularly adapted to the lighting of small areas either for general illumination or for some specific operation. The spacing of such units out of doors should in general not exceed three times their mounting height. It is consequently necessary to have a number of poles or favorable building locations in order to apply this form of lighting. Since maintenance is a serious problem at steel plants, the equipments used should be as nearly dust tight and weather proof as possible.

Floodlights, unless very skilfully employed, are likely to be in general the least satisfactory of the three possible types of lighting units. A floodlight projector confines the light within a certain angle, usually comparatively narrow, and is characterized by high beam candlepower with consequent glare. It is desirable that floodlightning units be mounted at a height of 30 feet or more and particular care be taken in their focusing. For spotting some particular point such as a storage bin or gateway the floodlighting unit is excellent.

For the general lighting of yards and driveways about a steel mill standard pendant street lighting units seem to be the best adapted. They can be made practically dust-tight and their distribution of light is such as to make possible a spacing equal to from 4 to 6 times the mounting height. This street lighting equipment is standard material and constructed for the hardest outdoor service. Their use is therefore accompanied by the least possible attention.

Because of the large areas involved, it is economical to use larger lamps and fewer of them than to use many small lamps. Consequently, the most common sizes of lamps are the 300 and 500 watt Mazda, while in many cases 1000 watt lamps can be used to advantage. It is important in any installation to keep the equipment reasonably clean and to renew burned out lamps and those which have burned beyond rated life and have consequently become blackened.

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*The Application of Synchronous Motors in Steel Mills**

By HARRY A. WINNE†

THE synchronous motor is not at the present time applied in steel mill service to nearly as great an extent as in some other industries. (This statement and, in fact, the whole of this paper, refers to motors furnishing power for machine, roll, and other drives). Nevertheless, there is a field for it, and it will perhaps be profitable to spend a little time studying its operating characteristics and trying to determine when it should be employed.

Motors for Miscellaneous General Purpose Drives

Let us first consider the possible application of synchronous motors to what may be termed miscellaneous general purpose drives, as distinct from main roll drives, which will be treated later. Synchronous motors are now readily available in capacities ranging upward from 20 h.p. at 1200 r.p.m. for operation on 60 cycle circuits at standard voltages. The demand for 25 cycle units of small size has not been sufficient to warrant the development of a standard line of general purpose synchronous motors for this frequency, but such units can be obtained.

In this field the synchronous motor is, of course, the competitor of the squirrel cage induction motor, and it is, therefore, of interest to compare these two types.

Power Factor

From the standpoint of operating power-factor, the synchronous motor is inherently superior. The power-factor of the induction motor is always lagging—not very much so in a high speed machine at full load, but seriously at the lighter loads at which the machines are too often operated, and in slow speed motors. The power-factor of the synchronous

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machine should be unity or leading at full load, with the amount of lead increasing as the load decreases. The majority of small synchronous motors are designed for unity power-factor at full load, although both 90% and 80% power-factor machines are sometimes used. The leading power-factor motors are much more expensive, larger, and less efficient.

Efficiency

As regards efficiency, the unity power-factor synchronous motors are superior to induction motors, except at part loads on the smaller sizes. Figure 1

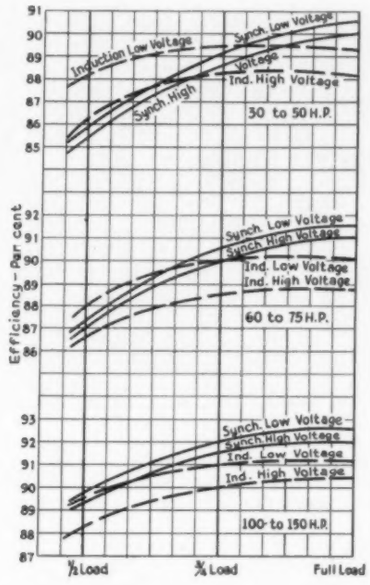

FIG. 1—Comparative efficiencies of synchronous and induction motors for miscellaneous general purpose drives.

gives a clear idea of the comparative efficiencies of the two types of motors. In larger machines than those covered by the curves shown, the difference is even more marked, reaching 2.5% or even 3% in some cases. Motors operating at 80% power-factor have efficiencies considerably below those of the unity power-factor machines, especially in capacities below 200 h.p. In the smaller sizes the efficiency of an 80% power-factor synchronous motor is less than that of an induction motor.

Starting Torque

The starting torque of the synchronous motor is usually better than that of the corresponding squirrel-cage induction motor, and at least 100% pull-in torque can be obtained, so that with one of the standard general-purpose synchronous motors it is easily possible to start and synchronize while delivering full rated torque. The synchronous machine has better starting characteristics than the induction motor, because while both utilize a squirrel-cage winding for starting, that on the synchronous motor is designed purely for starting purposes, while that on the induction machine must be designed primarily to give good operating characteristics after the motor is up to speed.

Cost

The first cost of small-sized synchronous motors is considerably higher than that of induction motors, but as the capacity increases, the disparity in cost decreases, and in large sizes, say, 300 h.p.-600 r.p.m., and above, the synchronous machine usually has the lower cost.

The approximate ratio of the cost of synchronous motors to that of corresponding induction motors is shown graphically in Figure 3. In making this comparison, the cost of complete hand control apparatus is included for both types, as well as that of direct connected exciters for the synchronous motors. If direct-current is available, as it always is in a steel mill, the exciter can be omitted and the cost ratio is then much more favorable to the synchronous motor than the curve shows.

Maintenance

As for maintenance expense, no comparative figures are readily available, but it seems reasonable to expect that there would not be a great deal of difference between the two types of motors except when the synchronous machine has a direct connected exciter. This feature would conceivably increase somewhat the maintenance cost of the drive.

The mechanical construction of the synchronous motor can be made fully as rugged as that of the usual induction motor. It fact, standard induction motor frames, end shields, and bearings are often used. The synchronous motor has the advantage of a much larger air-gap than can be incorporated in an induction machine, which helps to decrease maintenance.

Application

Now, turning to consideration of the field of application, it is evident that if good power-factor and high efficiency were of no value, we would never think of using the synchronous motor. However, we know that power to supply losses does cost money, as do generator capacity to supply wattless kv-a. and cables and switches to carry it. It is by comparing the cost of these factors with the dif-

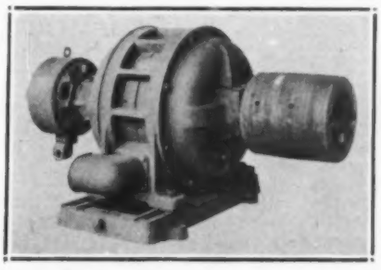

FIG. 2—75 h.p. unity power-factor 1200 r.p.m. general purpose synchronous motor with direct connected exciter.

ference between the cost of a synchronous and an induction motor that we can determine whether the use of the synchronous machine is justifiable.

In most steel mills power costs are comparatively low and it is difficult to justify the increased cost of the small synchronous motor on the score of efficiency. However, if the drive is of such a nature that the motor will run fully loaded a good portion of the time, this point should be very carefully investigated. Similarly, as regards power-factor correction, most mills have such a large power load that the corrective effect of a small synchronous

motor is not worth a great deal; but in a manufacturing plant where a few such motors may constitute the major portion of the load, and where the power cost may be appreciably affected by power-factor as well, it is obvious that the better efficiency and power-factor of the synchronous motor will often more than counter-balance any difference in first cost.

For slow speed small capacity drives, such as on direct connected air compressors and the like, the synchronous motor is usually employed because of the very poor power-factor and high cost of small slow speed induction motors. There is an interesting feature in connection with the application of synchronous motors to reciprocating compressors. Due to the pulsating torque required by the load, the drive must have a suitable flywheel, otherwise the motor may pulsate or hunt sufficiently to fall out of step. The size of the flywheel must be carefully determined in order to limit the pulsations to a safe value. At first thought it appears ridiculous to use a flywheel on a synchronous motor, but here is one application where it is absolutely necessary.

The synchronous motor should always be given very careful consideration for all constant speed drives above, say, 200 h.p. In these capacities the synchronous motor will cost little more and may cost less than the induction machine, and it will certainly have better efficiency and power-factor. The high efficiency is a particularly important factor when the motor will run continuously, or nearly so, at full load, as is the case on many pump and compressor installations. That this fact is well appreciated is

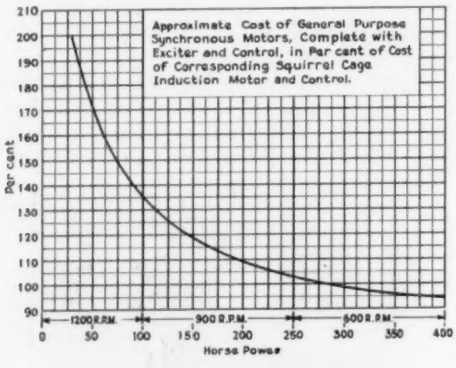

FIG. 3—Comparative costs of synchronous motors and induction motors for miscellaneous general purpose drives.

evidenced by the number of synchronous machines which are now in service driving water pumps, compressors, and the like.

MOTORS FOR MAIN ROLL DRIVES

Now let us discuss the application of synchronous motors to main roll drives, a subject which is of great interest to all electrical engineers connected with the steel industry. Motors for this service are ordinarily of such size that any possible gain in efficiency or power-factor must be given extremely careful consideration, and the synchronous motor does offer this possibility.

In connection with main roll drives we must, of course, compare synchronous motors with induction motors of the wound rotor type, as this is practically the only type of induction machine used for this service. In making any such comparison probably the question of starting characteristics is the first one that presents itself to most people, and rightly so, because if a drive won't start, it doesn't make any difference how well it runs.

Starting Characteristics

There exists more or less unfounded prejudice against the use of synchronous motors for mill drives, because their starting characteristics, that is, starting torque per kv-a. input, are admittedly poorer than those of the usual wound rotor induction mo-

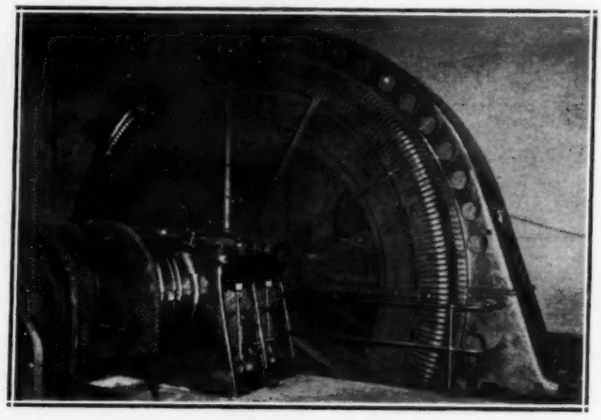

FIG. 4—9000 h.p.—unity power factor—107 r.p.m.—6600 volt synchronous motor driving continuous sheet bar mill at the plant of the Corrigan-McKinney Steel Co., Cleveland, Ohio.

tors. Granting this, the question is whether the starting ability of the synchronous drive is good enough for some types of mills. If so, its other desirable features may dictate its use.

Not long ago an article in a technical magazine made the statement that during the starting period the synchronous motor acts as a squirrel-cage induction motor, and that due to its poor starting characteristics the squirrel-cage motor is not considered for main roll drive. The implication was, of course, that synchronous motors should not be considered for such service. Both of the above statements are absolutely true, but the fallacy of the implied conclusion lies in the fact that the rotor winding of a squirrel-cage induction motor must be designed primarily to give good efficiency in regular operation, with starting a secondary, though important consideration. On the other hand, the squirrel-cage or amortisseur winding of the synchronous motor can be designed solely to give good starting performance, as it has virtually no effect on the normal operation of the motor.

That very good starting characteristics can be obtained by proper design is evidenced by the successful operation of the synchronous motors already in service. Figure 5 shows the approximate starting torque and kv-a. curves for the 9000 h.p. synchronous motor now operating in the Corrigan-McKinney Steel Company's Cleveland plant. These curves give the values obtained with full rated voltage applied. Actually the motor is started at reduced voltage obtained from an auto transformer, and the starting torque and kv-a. decreases proportionally to the square of the voltage. Starting on a 32% voltage tap gives a torque about 27% of normal

full load value, with an input of approximately 5000 kv-a., or 70% of normal kv-a. This starting torque has proved entirely adequate.

The amount of so-called "pull-in" torque available is also of importance, for if this is not sufficient to overcome the mill friction, it is obvious that the motor can never be synchronized. The pull-in torque is usually defined as the value available at 95% synchronous speed, for if a motor can bring its load up to this speed it will pull into step when field is

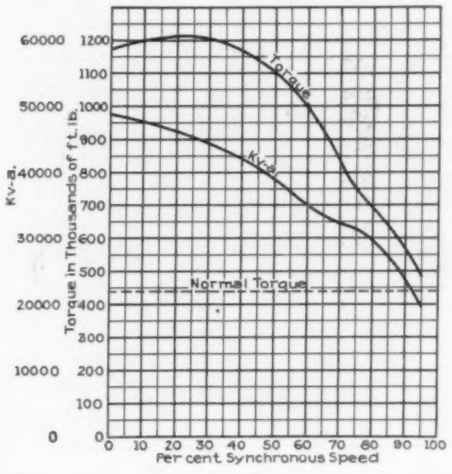

FIG. 5—Starting characteristics of the 9000 h.p. — 107 r.p.m. — synchronous motor at the Corrigan-McKinney plant.

applied. The pull-in torque does not need to be as great as the starting torque, for the latter has to overcome the static friction of the mill, and may have to back out a cobble as well.

It will be observed from Figure 5 that on this particular motor the pull-in torque for a given voltage is about half the starting torque. This proportion, of course, will vary in different machines and can be changed at the will of the designer.

It is usually possible to design the motor so that 100% of rated kv-a. input at starting will give from 35% to 60% of full load torque, and so that 100% kv-a. input at 95% speed, or "pull-in", will give 25% to 80% normal torque. The lower values of torque will be realized on 60 cycle motors with large numbers of poles.

Usually the control equipment on a wound rotor induction motor permits a starting current of about 150% of normal. On the corresponding synchronous motor a kv-a. input of 150% will in virtually all cases give a starting torque of at least 50% normal, and this is more than ample for many types of mills. The starting current for the synchronous motor will, of course, be at lower power-factor than for the induction motor, and therefore somewhat more disturbing to the power system.

Plugging

A synchronous motor can be plugged to bring it quickly to rest, or to reverse it, as easily as can an induction motor. At the same voltage the plugging current will be only about 15% more than the starting current, and the plugging torque about 25% less than the starting torque. Therefore, it is not at all necessary to have a separate compensator tap for plugging.

Maximum Torque

A synchronous motor can be designed for fully as high maximum or pull-out torque as an induction motor, and it possesses the advantage that as the applied voltage decreases, its torque decreases only in direct ratio to the voltage, whereas the torque of an induction motor varies as the square of the voltage. That is, a drop of 10% in voltage will decrease the available torque of the synchronous motor only 10% while that of the induction motor will drop 19%. Furthermore, because of the better power-factor of the synchronous motor, the drop in line voltage due to a given load on the motor is not likely to be so great as if an induction motor were used. The synchronous motor helps to maintain the voltage at its terminals.

Efficiency

The efficiency of a synchronous motor is usually from 0.5% to 2.0% better than that of the corresponding induction motor. The greatest difference occurs on slow speed 60 cycle machines. This better efficiency means actual savings in dollars and cents.

Power-Factor Correction

Perhaps the most desirable feature of the synchronous motor is its ability to furnish leading reactive kv-a. for power-factor correction. Synchronous motors for main roll service are usually designed for 80% leading power-factor at full load. Figure 6 shows for both unity and 80% power-factor motors the approximate amount of leading reactive kv-a. available at loads other than normal, with the field excited at the full load value. The curves given are only approximate, and values will vary considerably for different motors. It is evident

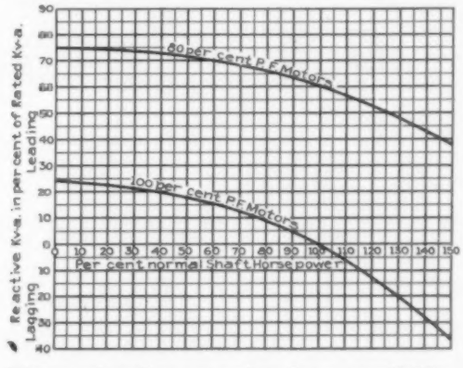
80 per cent P F Motors
100 per cent PF Motors
Reactive Kv-a. in per cent of Rated Kv-a.
Leading
Lagging
Per cent normal Shaft Horse power

FIG. 6—Leading reactive kv-a. available for power factor correction at different loads on synchronous motors with field excitation held constant at normal load value.

that even at 150% load an 80% power-factor machine still furnishes a considerable amount of correction.

The fact that slow speed 60 cycle induction motors operate at undesirably low power-factors has necessitated the use of reduction gears in many cases where for other reasons a direct drive would have been preferable. A synchronous motor, however, has a good power-factor regardless of its speed, and hence may make possible direct drive where an induction motor would require gearing.

Speed Regulation

A synchronous motor, of course, runs at constant speed, providing the line frequency is constant, and

this prohibits its use on any drive requiring a flywheel, since the wheel can liberate stored energy only by slowing down. Obviously, it cannot be employed when speed adjustment is required. On the other hand, in the case of a continuous mill the product of which is cut into lengths by a flying shear, the absolutely constant speed of the synchronous motor will insure uniformity of length of the finished pieces.

Excitation

A synchronous motor requires d-c. excitation which may be obtained either from a direct connected exciter or a separate exciter set. The excitation voltage should always be 250, so that the usual 250 volt d-c. mill circuit may be used as an emergency supply.

The induction motor has the advantage that it requires no separate excitation.

Space Requirements

The amount of floor space required by a motor is sometimes a very important factor, and in this respect the synchronous motor almost invariably has the advantage. It is usual practice to make the base of a main roll motor long enough so that the stator can be moved along the shaft to make both rotor and stator windings accessible for cleaning and repairs. Due to the greater axial length required for the end connections of the rotor coils on an induction motor, the length of the rotor is usually greater than that of the corresponding synchronous motor, necessitating a greater total length.

If the motors under consideration have a large number of poles, the induction motor must be of disproportionately great diameter, in order to obtain reasonable power-factor, so that it may be both wider and longer than the corresponding synchronous motor. Table I give comparative dimensions of typical motors of both types.

TABLE I.

COMPARATIVE DIMENSIONS OF SYNCHRONOUS AND INDUCTION MOTORS

	Synchronous Motor	Induction Motor
Rating	28 poles—9000 h.p.	
Length of base	18 ft. 0 in.	20 ft. 7 in.
Width of base	26 ft. 6 in.	25 ft. 0 in.
Floor space	477 sq. ft.	515 sq. ft.
Rating	72 poles—5000 h.p.	
Length of base	16 ft. 2 in.	15 ft. 9½ in.
Width of base	20 ft. 3 in.	29 ft. 11 in.
Floor space	327 sq. ft.	472 sq. ft.
Rating	10 poles—1500 h.p.	
Length of base	10 ft. 10 in.	12 ft. 3 in.
Width of base	11 ft. 8 in.	11 ft. 9 in.
Floor space	126 sq. ft.	144 sq. ft.

First Cost

The first cost of motor complete with all control and accessories is usually slightly less for the synchronous than for the induction type if the speed is moderate, and materially less if the speed is low. This is true principally because the rotating field structure of the synchronous motor is inherently less costly than the rotor of an induction motor.

Maintenance

As far as the possibility of trouble is concerned, it would seem that the two types of motors should be about on a par, although the larger air gap of the synchronous motor is in its favor. If an electrical breakdown does occur in the stator winding, one machine should be as easy to repair as the other. Any trouble with the field winding of the synchronous machine would perhaps be easier to repair than a breakdown of the rotor of an induction motor.

Because of the difference in rotor construction, it is easier to clean the windings of a synchronous motor than those of a wound rotor induction machine. On the synchronous motor this cleaning can often be done without moving the stator.

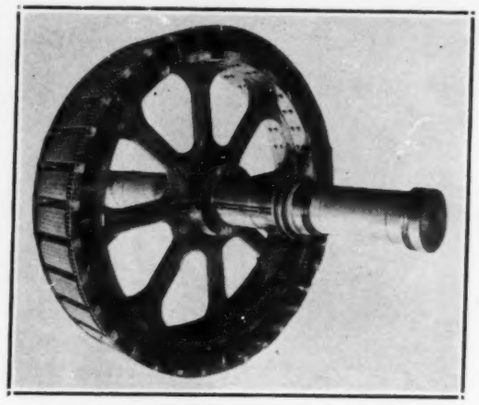

FIG 7—Rotor of 4000 h.p.—83 r.p.m. mill type synchronous motor. This general construction used for large slow speed motor.

Construction

There is no reason why the general construction of a synchronous motor cannot be made just as rugged and reliable as that of a mill type induction motor, and in those machines which have been built for main roll service by the company with which the writer is associated this has been done.

The rotor spiders are of steel, those of small diameter being made up of laminations of steel plate, while the larger ones are steel castings. The pole-pieces are laminated and held securely in place by dovetailed extensions or by bolts which screw into solid steel keys imbedded in the pole-pieces. The two types of rotor construction are shown in Figures 7 and 8.

The field coils are usually of edgewise-wound bare copper strip, with paper insulation between turns. The amortisseur winding is made of copper alloy bars and connection straps. The end connections have bolted joints between poles, so that any one pole may readily be removed.

The stator frames are either cast, or fabricated of steel plates, with the laminations of the core securely held in place by dovetailed keys and clamped between heavy finger flanges.

The stator coils are held in the slots by wedges and the end connections are securely laced to insulated steel rings supported on the stator frame, thus preventing distortion by heavy current surges.

The pedestals are of the same heavy mill type used on other main roll motors.

Control

The control equipment for a synchronous motor can be arranged so that from the mill operator's standpoint it is just as simple as that for a d-c. or induction motor. He simply throws a standard type of master switch to the running position, and the motor starts, comes up to speed, and has field

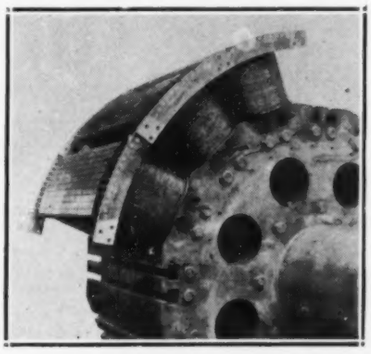

FIG. 8—Partially assembled rotor of 6500 h.p.—187 r.p.m. mill type synchronous motor. Note the laminated plate spider used for comparatively small diameter rotor.

applied automatically without further attention on his part.

The main equipment required consists of oil circuit breakers, an auto-transformer, and a relay panel. An elementary diagram of the connections of breakers and auto-transformers on a 9000 h.p. motor is given in Figure 9. The two-step "Korndorfer" method of starting is used, the sequence of operation

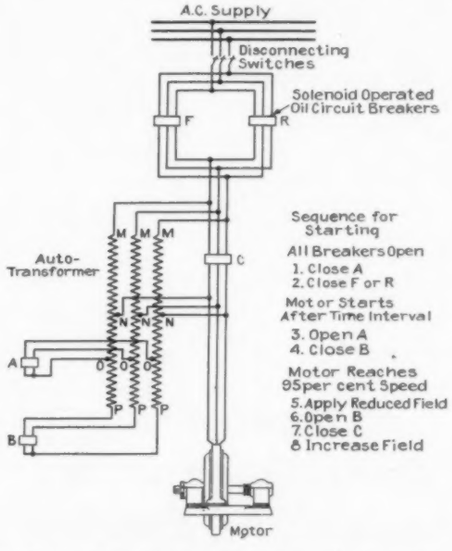

FIG. 9—Elementary diagram of connections of two-step Korndorfer starting system for synchronous motor.

being as follows: When the master switch is thrown forward, breaker "A" closes, followed immediately by breaker "F". This applies a low voltage to the motor, starting it. After an interval determined by a timing relay, "A" opens and "B" closes, applying a higher voltage to the motor. As soon as approximately 95% synchronous speed is reached, as indicated by the operation of a centrifugal switch, a weak field is applied, pulling the motor into step. Then breaker "B" opens, followed by the closing of "C", connecting the motor to full line voltage, after which the excitation is raised to the normal value.

The Korndorfer system of starting differs from the usual compensator method in that the motor is not entirely disconnected from the circuit when changing from one voltage to another. That is, when transferring from the starting voltage to the second step, after "A" opens and previous to the closing of "B", the motor still receives power through the auto-transformer acting as a reactor. The same thing occurs when shifting from the second tap to line voltage.

Protection against overload, undervoltage and loss of excitation is provided. A timing relay in-

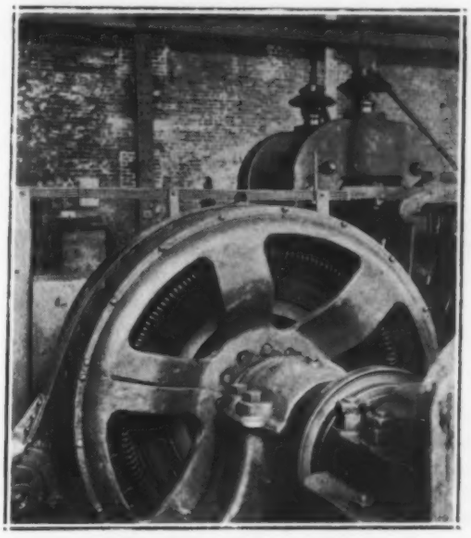

FIG. 10—500 h.p.—360 r.p.m. super-synchronous motor driving a brass rolling mill.

sures that if the entire starting cycle is not completed within a predetermined time, all breakers will be opened.

Installations

The largest synchronous motor—and in fact, the largest motor of any type—which has yet been installed in main roll service is the 9000 h.p.-107 r.p.m.-6600 volt unity power-factor machine now driving a continuous sheet bar mill at the Corrigan-McKinney Steel Company, Cleveland, Ohio. This motor has now been in very successful operation for almost one year. It has never failed to start the mill, has been plugged, and has backed out cobbles, meeting all demands without difficulty. It is operated on a system whose generating capacity is very small as compared to the size of the motor, and during the starting cycle, when transferring from the second tap to the line, some voltage disturbance is caused. Steps are being taken which will overcome this annoyance. The motor is started at 32% normal voltage, which gives a starting torque about 27% of normal with an input of 5000 kv-a.

Two large synchronous motors are now being installed at the Sparrows Point Plant of the Beth-

lehem Steel Company to form part of a continuous skelp mill drive. One of these is rated 16 poles-6500 h.p.-0.8 p.f.-187.5 r.p.m.-6600 volts. The other is rated 36 poles-4000 h.p.-0.8 p.f.-83.3 r.p.m.-6600 volts.

A synchronous motor to deliver 5000 h.p. at 240 r.p.m. is now being built to drive a seamless tube piercing mill, at the plant of the Standard Seamless Tube Company, Economy, Pa. Several smaller synchronous motors are already in operation on tube piercing and rolling mills.

Super-Synchronous Motors

Two 500 h.p.-360 r.p.m. motors of the so-called "super-synchronous" type are operating very satisfactorily on copper rolling mills. This type of motor

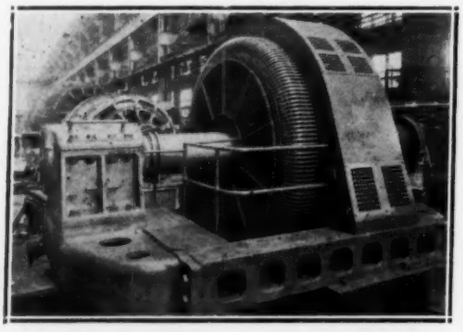

FIG. 11—Mill type synchronous motor rated 6500 h.p.—0.8 p.f.—187.5 r.p.m.—6600 volts, assembled on the Manufacturer's testing floor.

is somewhat like an ordinary motor of the end shield bearing type, except that the whole machine is supported by two pedestal type bearings, and the stator may rotate around the shaft, being supported by the end shield bearings. Except during the starting operation, the stator is restrained from rotating by a band brake around its external periphery. The general construction of such a motor is illustrated in Figure 10.

When starting a super-synchronous motor, the brake is first released and then the usual procedure for starting a standard motor is gone through with. However, since the stator is free to rotate, while the rotor is connected to the load, the stator, and not the rotor, comes up to speed. Now, since the motor, that is, the stator, is running, with field excited, the full maximum pull-out torque of the motor is available for starting the load, which is accomplished by gradually applying the brake, bringing the stator to rest and causing the rotor to come up to full speed.

The super-synchronous motor will, therefore, start any load it can carry without pulling out of step, and it may be applied in many instances where the standard type of motor would not be successful. Its mechanical construction is somewhat more complicated and it is considerably more costly than the ordinary synchronous machine.

Field of Application

Possibly the easiest way to define the boundaries of the field of application of synchronous motors to main roll service is to tell first where they should not be used. They obviously are not applicable to reversing drives, to mills requiring adjustable speed, nor to mills equipped with flywheels. Difficulty may be experienced if synchronous motors, unless of the super-synchronous type, are applied to sheet and tin mill cold rolls, as the starting duty, owing to excessive mill friction, is very heavy. Cold strip mills are frequently required to start with metal in the rolls, and the advisability of applying synchronous motors to such mills is very questionable.

Now as to mills to which synchronous drives can be applied, the constant speed stands of continuous billet, sheet-bar, skelp, rod, and similar mills seem to offer an ideal field. The starting duty is not hard, as it is not the practice to try to start the mill with metal in the rolls, except in the reverse direction to back out a cobble, and backing out requires little more torque than starting the empty mill. The success of the motors already installed on seamless tube piercing and rolling mills presages their further use on mills of this type.

In fact, it may be said that the synchronous motor is a contender for the drive of any hot metal rolling mill which does not require speed adjustment, the use of flywheels, nor frequent reversal. For any such drive it should be given full consideration, with careful thought as to both its advantages and disadvantages.

General Conclusions

The high efficiency and power-factor of the synchronous motor warrant its careful consideration for constant speed general purpose drives of possibly 50 h.p. and greater capacity. The minimum capacity of drive at which the synchronous motor should begin to be considered will, of course, vary in different installations, depending on size of power system, existing system power-factor, and cost of power.

Experience has already demonstrated the entire practicability and desirability of using synchronous motors for driving some types of metal rolling mills. The usual large capacity of such units makes high efficiency and power-factor of extreme importance. It is certain that synchronous motors will be widely employed in this service in the future, and it is the problem of the engineers who are responsible for the purchase, application, and design of these machines to see that they are used not only widely, but wisely.

Registration
Annual Convention and
Iron and Steel Exposition

Registration Headquarters for the Convention and Exposition will be at the Pittsburgh Athletic Association Annex (Old University Club). This club is about 100 feet from the Syria Mosque where the Exposition is being held.

*Safe Practices in Connection with the Operation of High Tension Power**

By A. N. CARTWRIGHT†

THE subject of safe practices in connection with the operation of high tension power is quite broad in its application, but for the subject of this paper I have brought it within the confines of the actual operation of the substation and the transmission lines connected thereto. The subject as a whole naturally divides itself into two main factors, safe practice with relation to the employe and to the public, and safe practice with relation to the apparatus and to the service. Some of the points brought out are very definite in their relation to the practices involving the human interest and other points are equally definite regarding the mechanical element, although in a very large measure, the two elements are correlated.

The operation of high tension power facilities by well organized companies has become fairly well standardized without any effort on the part of the operating companies to create one standard of operation. There, of course, has been considerable interchange of thought and experience but for the most part, the logical answer to most questions was evident when the proper values were known and placed on the various questions involved. In the public utility power company this particular operation is under the jurisdiction of a system operation or load dispatching division which is under the general operating department and is supervised by a man of long experience who is chosen for his particular ability along the very line of work which this operation involves. This man is never the optimist but is of the "show me" type. He must be resourceful, have accurate thinking power, quick with judgment, and have most of his planning done before the actual need for action arises. In addition to this, the man should have a mental picture of all of the apparatus which he is to operate, together with its location, relation to other apparatus and the possibility of trouble extending beyond the point of origin. This information should be supplemented by records to complete his absolute knowledge of the situation, these records to be in readily available form so that they can be used with the least possible delay. This means that the man or men in charge of this operation must make necessary frequent visits to all points of operation that they may know and keep familiar with all the details. They must be able to judge the men to whom they are giving orders, knowing the strength and weaknesses of these men, so that they can take full advantage of their additional abilities whenever the need arises and to emphasize a point to a man when the operation may be one of his weaknesses. As an example, in cases of trouble or emergency one man might be calm and give an excellent description of the trouble and have very logical and proper suggestions for further action, where another man might be of excitable nature during the same emergency and liable to give descriptions and sequences of happenings which may not be correct without any intention on his part to make misstatements. It is then the system operator's or dispatcher's duty to steady this man and check that the information he is getting is that of the actual condition.

The successful substation operator is all of the above to a lesser degree. The type of man for this work is the man who is not overly ambitious for higher position but one who is rather willing to make the operating job a possible life job and, therefore, think seriously along the lines of his particular duties. Certain mistakes will be made in the operation and are not unexpected with new men. It is, therefore, desirable to change men as infrequently as is possible. Certain mistakes are considered by the operating companies as a part of the education of the operator and the type of mistake may indicate whether the man is a type that will develop as you desire or whether it is necessary to replace him immediately.

Placing the above human equipment first, where it logically belongs for the successful operation of high tension power, I will now follow with some of the details describing the basic principles which can be applied to any similar situation in modified form but going into these only far enough to give a working knowledge of the requirements.

Normal Operation—System in active state serving the load requirements.

To constantly maintain the system under this condition is the ideal for which we are striving. The power company's greatest facility for so doing is the communication system. This must be as quick, direct, efficient and always available as possible. Any interruptions to service are normally extended to just the extent of delays in telephone communication. (This, of course, applies to interruptions beyond the limit for which station rules would apply.) A telephone line on or adjacent to a transmission structure has a very important function in allowing a line that has been out of service for maintenance or repairs to be restored to service immediately on the completion of the job. Its location in this manner also has an important function in reducing the hazard to life and service if more than one circuit is carried on the structure. However, if the telephone line is carried on the same or closely adjacent structures to the transmission lines, precautions must be taken that it does not cause a hazard in itself.

As a measure of the importance of communication, the speaker's company has physical telephone lines connecting all high voltage operations with the exception of a few relatively small branch lines and customers' substations. The major portion of this telephone system has two or more lines of communication or separate sources to the point to be reached. In addition, all attendant substations are equipped

*To be Presented at Annual Convention, June 13th to 18th, 1927, Pittsburgh, Pa.

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with commercial telephones and again supplementing the above, space radio using voice transmission has been installed between three important points on the system and the success of the experiments being carried on will determine to what extent additional use of this facility will be made.

There must be station rules of well thought out simple orders applying to the individual station to govern the action of the operator in the event of loss of service to some or all of his equipment and which will allow him to restore service, if possible, without the delay of getting into communication with the system operator or dispatcher.

Another of the essential tools of operation is a schematic diagram of the system to be operated. This can be as simple or as elaborate as desired but must be kept religiously abreast of any changes made on any of the facilities of the system. All facilities should have designation symbols on this diagram as distinctive and as different from each other as possible to avoid mistakes during hurried periods. This system diagram should be mounted in a position where it can be seen and studied while the dispatcher is making use of the phone. This diagram should give an accurate picture of the system such as the mechanical as well as the electrical relation of each facility to other facilities and when in use should indicate the true condition of the system at all times by designation of the facilities that are in a condition other than normal.

The system log is used in conjunction with this operating board. This log consists of a classified chronological statement of every operating event, condition of all equipment out of service and any hazardous conditions that may exist on the system. It serves as an additional record of the condition of the system relieving the load dispatcher of remembering events and serving as a source of information to the next load dispatcher that comes on duty.

The following are some of the general rules which in normal operation guard service and life:

1. No high voltage equipment may be removed from or returned to service during peak hours except by special permission.
   (a) Switching on lines and equipment is limited and the business of the day is confined to the delivery of service.
   (b) Elimination of switching errors at a time when the worst effect to the service could occur.
   (c) General restriction of maintenance work during the period of the system's greatest activity.
2. Advance notice required (usually 24 hours) to have high voltage line or equipment out of service to be worked upon and then such equipment must be removed from and restored to service during "off peak" hours.
   (a) Important tie lines or generating equipment not permitted out of service during peak hours.
3. Hourly inspection required of all station galleries and switchyards by operators.
   (a) Inspection brings to light many faults before they become troubles.
4. Employes other than the operator and all visitors refused admission to high voltage gallery or yards unless accompanied by the operator or properly appointed guard.
   (a) Elimination of hazard to service or equipment due to activities adjacent to operating equipment.
5. Men working on lines and operators in station are required to report to nearest station or load dispatchers by 'phone at least once per hour.
   (a) Reports required that dispatcher may know the exact condition of the system at all times and to allow for the quick restoration to service of any line or apparatus that has been taken out of service for regular maintenance work or if for emergency repairs to be in touch with the actual conditions and operate the system accordingly.
6. One or more men constituting a so-called "gang" when working in the vicinity of live equipment, are required to have mechanical guards between their work and live equipment wherever possible, and, in addition, must have a man whose sole duty it is to watch the workmen's actions, warning them against undue approach to live equipment and having power to recall any man who does not, in his estimation, take all the necessary precautions in connection with the work. Men working on steel structures on which high voltage equipment is energized are required, wherever possible, to work from ladders rather than on the structure itself. This rule is made to eliminate the possibility of a man inadvertently going beyond the deal line established in connection with his work.

   When a station or a line is being worked on for maintenance or emergency repairs, the next station adjacent to the point on which the work is being done, is required to have "Stand By" safety cards on the live lines which lead to or are in close proximity to the point at which this work is being done. The function of this "Stand By" card is to give notice to the operator that if a switch opens automatically on which a "Stand By" card has been placed, the service shall not be restored by closing the switch until he is assured that the automatic opening of the switch was not caused by work being carried on in an adjacent location, and that all men are clear.
7. Work is not permitted in two adjacent stations at the same time. This is to allow as much of the system to remain normal as possible and to minimize the effect of any trouble which may occur.
8. Testing of all kinds prohibited in generating stations and large output substations during peak hours.
9. No new construction, both in lines and apparatus, is put into operation until after it is inspected in detail and approved by the system operating department.

10. Routine patrol inspection of lines should be maintained, supplemented at regular and irregular intervals by trained special inspectors to pick up faults which the regular patrol inspector might not observe.

11. A complete scheme of tagging is used to definitely call some particular condition to attention, to serve as a warning sign to assist in checking operations, and to act as an instrument of record. Each of these tags has a definite color scheme with distinctive printing and is almost entirely self explanatory, the face of the tag indicating what use is to be made of the tag and also the record spaces. The reverse side contains rather complete instructions for use. We, of course, supplement these instructions with additional detail instructions and by general instruction orders. A careful analysis of each of these tags will indicate that they cover almost every situation surrounding an operation in the substation or switching equipment where the use of a tag has any merit or value. (See Fig. 1.)

Operation of Removing Lines and Equipment from Service and Returning Them to Service

A. All lines and equipment on the system on which the writer is employed are very definitely designated by name, numbers only being used when there are double circuits on the same line structure. These are then numbered No. 1 and No. 2. Careful consideration is given to the naming of each line and piece of apparatus. Each name is distinctive and has a very definite meaning. This is to give all parties concerned with an operation a very definite mental picture of just what is affected by each operation. All operators are trained to understand just what each operation involves, having a clear working knowledge of all reactions that ought to occur from every operation.

B. No lines or apparatus are taken out of service for work upon them except for people who have been definitely authorized to have charge of this work. No man can have charge of this work until having been in the employ of the company for a period of six months or more.

C. A load dispatcher's main assurance that an operation is being carried out correctly and safely is a simple but rather lengthy system of orders, checks and counter checks centering around the work permit or release order card.

1. There is free discussion between load dispatcher, substation operator and workman covering exact nature of work, specific equipment or line required for the work, the time to be consumed and the special orders involved in the particular situation. This occurs at a time prior to the actual switching operation and misunderstandings are eliminated, making the entire operation very definite and clean cut.

2. If interruption to service is involved, a positive check is made that permission from consumers has been secured.

3. Check is made upon the workmen to ascertain if they are sure of the exact equipment on which they are to work.

   (a) If work is to be done on a double circuit line with one side energized, the man in charge of the line work is required to be at the structure on which part of the work is to be done or as near that location as possible and to designate facing a particular station, whether the line on which he is to work is on his right or left side.

   (b) He is required to describe by structure number his location which is then checked by the maps.

   (c) An electrician at a station specifically describes between what points his work is going to be performed and must personally check where the circuits are open before he proceeds.

4. The necessary number of release order cards are prepared.

   (a) Each card contains all the necessary information without reference to any log or other card.

5. When a line or piece of equipment is de-energized, it is checked for being dead by pilot lights and condenser spark.

6. Two open places are required, one of which must be visible, to every line or piece of apparatus controlled by an automatic oil circuit breaker and each open point properly tagged.

   (a) Fuses are removed on the controls of the oil circuit breaker involved.

   (b) Potential fuses are pulled to prevent the line or equipment from being energized through meters or synchronizing equipment.

7. When there is one mechanical disconnect device such as an air break switch, after opening, it is locked in the open position and tagged.

8. All lines or equipment are grounded at the station.

   (a) Men working on a line must in addition protect themselves by establishing good protecting grounds at the point of their work.

9. The station operator reports to the load dispatcher in the hearing of a lineman or electrician just what he has done to de-energize and ground the line or equipment. The load dispatcher describes to the lineman or electrician just what he has done to de-energize and ground, where release order cards are placed, where "Stand By" orders are in effect, and, if there are any special orders, their exact nature and meaning, and lastly cautions him to ground his own equipment.

10. Restoring Lines or Equipment to Service.

   (1) In restoring lines or equipment to service, the lineman or electrician to whom the line or piece of equipment has been released is required:

INSPECTION ORDER

CARDS PLACED

NO._____

STOP

Only Operate This Equipment When Directed By the Person Holding This Inspection Order

DAY DATE 192

STATION

EQUIPMENT

AUTHORIZED BY TITLE

A. M. P. M.

REMOVED FROM SERVICE BY Time

A. M. P. M.

TO BE AVAILABLE BY TIME

INSPECTION ORDER IN CHARGE OF

A. M. P. M.

SIGNATURE TIME

INSPECTION ORDER COMPLETED BY

A. M. P. M.

PERSON TIME

A. M. P. M.

RETURNED TO SERVICE BY TIME

REPORTED TO TITLE

REMARKS

INSPECTION ORDER STUB

DATE 192

NO. OF CARDS

MR.

You Have An Inspection Order On

EQUIPMENT

STATION

THE EQUIPMENT Is / Is Not GROUNDED

YOU MUST CLEAR BY A. M. P. M.

OPERATOR

THE ABOVE EQUIPMENT Is / Is Not READY FOR SERVICE

ALL SHORTS AND GROUNDS Are / Are Not REMOVED

A. M. P. M.

SIGNATURE

Front of card. This card is printed in black ink on yellow background.

Form 1393
159379

WEST PENN SYSTEM

This INSPECTION CARD must be attached to equipment by the person preparing the equipment for an INSPECTION ORDER, only after all sources of power to said equipment have been opened and before any one works on it.

Only one person may obtain an INSPECTION ORDER at one time on any equipment, and that person must sign each INSPECTION CARD used to cover this equipment under "INSPECTION ORDER IN CHARGE OF." He asserts by signing each card that he is familiar with its meaning and all instructions pertaining to the INSPECTION ORDER which the card covers. All other persons wishing to work on this equipment must work under the direction of the person in charge of the INSPECTION ORDER.

The person in charge of the INSPECTION ORDER on any equipment is jointly responsible with the operator for all switching and operations to remove the equipment from service and to restore it to service. This person and the operator must check and make sure that the proper switching and operations have been made and completed. When possible this person must accompany the operator and check him during the actual work of removing from and restoring to service this equipment.

The equipment covered by this card and stub may be operated by the operator under the direction of the person in charge of the INSPECTION ORDER.

When the equipment covered by this card and stub is ready for service, the person in charge of the INSPECTION ORDER must sign this stub and return it to the operator.

Back of card. This card is printed in black ink on yellow background.

RELEASE ORDER

MEN AT WORK

Do Not Put Power On Lines Or Equipment Controlled By This Switch

DAY DATE 192

STATION

SWITCH

ORDERED OFF BY TITLE

A. M. P. M.

SWITCH OPENED BY TIME

LINE GROUNDED AT

A. M. P. M.

STATION TIME REMOVED

A. M. P. M.

STATION TIME REMOVED

A. M. P. M.

STATION TIME REMOVED

RELEASED TO

A. M. P. M.

PERSON TIME

A. M. P. M.

PERSON TIME

A. M. P. M.

PERSON TIME

MEN REPORTED "CLEAR"

A. M. P. M.

PERSON TIME

A. M. P. M.

PERSON TIME

A. M. P. M.

PERSON TIME

A. M. P. M.

ORDERED ON BY TITLE

A. M. P. M.

SWITCH CLOSED BY TIME

Front of card. This card is printed in black ink on red background.

Form 1392
159379

WEST PENN SYSTEM

This RELEASE CARD is one of the means used by the Operating Department for the service to, and the safety of the public and the employees of the WEST PENN SYSTEM. All rules and instructions must be rigidly enforced.

The name of each person given this RELEASE ORDER must be written in the place under "RELEASED TO" on this RELEASE CARD, and this card must be attached to each switch or circuit breaker (both of which are termed switches elsewhere) that controls lines or equipment after all sources of power to them have been opened, and upon which persons have obtained a RELEASE ORDER.

The lines or equipment controlled by this switch must never be energized while this RELEASE ORDER is in effect.

As each person given this RELEASE ORDER reports "CLEAR" his name must be written in the place under "MEN REPORTED 'CLEAR'," and this RELEASE CARD must never be detached from the switch until all persons holding the RELEASE ORDER have reported "CLEAR."

Back of card. This card is printed in black ink on red background.

(a) To report off in person.

(b) To guarantee, within the hearing of the station operator, that all men are in the clear and that all shorts and grounds placed by him have been removed.

(2) The routine step by step method of restoring lines or equipment to service includes giving the necessary orders, checking that the order is understood and finally, rechecking.

(a) As an example of the check method on the giving of orders, I will use a theoretical case of removing from service one circuit of a double circuit line between Charleroi and Washington, to allow a group of linemen to make an emergency repair upon No. 1 line.

The foreman in charge of the gang is at the location where the work is to be performed. He has called in through one or both of the stations to which this line is connected, using his portable safety 'phone. Having made connection with one or both of the stations he is consequently put in touch with the dispatcher. He informs the dispatcher that he is at the location of the trouble and ready to proceed with the work. The load dispatcher will check him as to location by structure number. He will make sure that he is to work on the proper circuit by asking him with his face towards Washington substation on what side of the line he is about to work. If he answers correctly that he is to work on the left side when he is facing towards Washington, the dispatcher then knows that the foreman understands perfectly which line

HOLD OFF CARD

HOLD OFF

DO NOT OPERATE THIS EQUIPMENT

EQUIPMENT _____

_____

STATION _____

DAY _____ DATE _____ 192

PLACED BY _____

REMARKS _____

_____

_____

_____

REMOVED BY _____

Front of card. This card is printed in red ink on a white background.

Form 1403
163164

WEST PENN SYSTEM

This HOLD OFF CARD must be placed upon the control points for equipment when said equipment has been removed from service and is hazardous to return to service but upon which no one is working.

This HOLD OFF CARD will be placed upon the control handle of a switch controlling the circuit on which someone is operating air disconnecting devices as the closing of said switch may be a hazard to any person operating such devices.

This HOLD OFF CARD will be placed upon any valve or switch which is hazardous to operate due to the valve or switch, or the line or equipment controlled by the same being defective.

Back of card. This card is printed in red ink on a white background.

is to be dead and on which he is to work.

The dispatcher will then ascertain that all the operators who are to do switching and to remove the line from service are on the telephone and listening in. (Each operator is responsible to check with the load dispatcher the entire switching procedure of removing or restoring a line from service.)

The line will be ordered open at both ends as follows:

"Open Washington No. 1 switch at Charleroi," the Charleroi operator repeating this order back word for word and being checked OK by the load dispatcher before he proceeds with the switching. A similar order is given to Washington operator as follows: "Open Charleroi No. 1 switch at Washington." The Washington operator repeats this order back word for word and having received the confirmation, he proceeds with the switching.

Immediately after each operator has performed his ordered operation, he comes back on the telephone and reports to the load dispatcher: "Washington No. 1' or "Charleroi No. 1 switch is open at Charleroi" or "open at Washington," as the case may be. The load dispatcher repeats this report and the station operator checks that it is OK. This is followed by the continued operation of checking the line for being alive, grounding same if it is OK, removing fuses from the control circuit, etc., opening proper disconnect switches, and re-

STAND BY ORDER

STAND BY

LOOK OUT FOR TROUBLE

DAY DATE 192

STATION

EQUIPMENT

STAND BY ORDER GIVEN TO

MR.

LOCATED AT

REMARKS

ORDERED BY TITLE A. M. P. M.

GIVEN BY TIME

STAND BY ORDER REMOVED

ORDERED BY TITLE A. M. P. M.

RESTORED BY TIME

Front of card. This card is printed in black ink on a green background.

Form 1404
163164

WEST PENN SYSTEM

This STAND BY ORDER CARD must be attached only to switches and their control points that are in service, and control lines or equipment on or near which persons are working.

If any trouble occurs on any lines or equipment controlled by a switch while this STAND BY ORDER CARD is attached to it, the operator must not attempt to restore service until he has assured himself that the person holding this STAND BY ORDER CARD is "CLEAR" and everyone is safe, or he has received definite orders from the Load Dispatcher concerning the same.

Back of card. This card is printed in black ink on a green background.

porting to the foreman in charge of the work to be done that the line has been removed from service, with full description of all switches and disconnects that are open, and grounding for his protection. All conversation during this switching operation is repeated back to and OK'd by the party who originates the conversation or orders.

The foreman in charge of the work is informed that No. 1 Charleroi-Washington Line is open and grounded at Charleroi and Washington; that release cards have been placed on the switches and grounds bearing his name and "Stand By" tags have been placed on No. 2 circuit switches at both Washington and Charleroi, and to proceed with the work, cautioning him that the No. 1 circuit is on the left with his face towards Washington and to establish his own grounds before starting to work.

The above will, no doubt, seem lengthy and time consuming. It may also seem unnecessarily safe, but it must be borne in mind that life is involved and that telephone lines are not always in perfect operating condition, and at times it is rather difficult to understand orders and conversation of such exacting detail and of such importance over them. This same checking procedure has been in effect on the system on which the writer is commenting for a period of over fifteen years, and we have been unable to shorten the procedure without losing the assurance of proper operation being always performed by dispatching over telephone lines. This checking arrangement has allowed the relay of orders where through line connections to the dispatcher were impossible and is one of the few operations which seem to be absolutely air-tight from a safety standpoint.

CONSTRUCTION CARD

NEW WORK

THIS EQUIPMENT IS UNDER CONSTRUCTION

EQUIPMENT _____

_____

STATION _____

DAY _____ DATE _____ 192

PLACED BY _____

REMARKS _____

_____

_____

_____

REMOVED BY _____

Front of card. This card is printed in black ink on a blue background.

Form 1402
163164

WEST PENN SYSTEM

This CONSTRUCTION CARD is to be placed upon all equipment that is under construction or that has not been placed in operation, and which is located near or in the vicinity of equipment that is under the jurisdiction of the Operating Department.

The Operating Department has no jurisdiction over and will not operate any equipment to which this CONSTRUCTION CARD is attached.

The Construction Department must not operate any equipment that is under construction, or that has not been placed in operation, and which is located in the vicinity of equipment under the jurisdiction of the Operating Department, unless the equipment the Construction Department wishes to operate is tagged with this CONSTRUCTION CARD.

Back of card. This card is printed in black ink on a blue background.

The operators are under a constant coaching system both by the dispatchers and men whose duty it is to visit each station, checking over the station equipment and the operators' understanding of rules and orders, putting up to the operator hypothetical problems of trouble, receiving the operators' answer as to what his action would be under the propounded condition and making him understand the proper operation that he should perform in the situation under question. This is carried on in a more intensive way with the dispatchers themselves by meetings, having round table discussion, lectures and examinations.

Analysis is made of all operating errors and, if possible, rules are formulated to prevent their recurrence.

Neglect of the rules or inexcusable mistakes are followed by dismissal or transfer to a less important position. In addition to the above, the operators are supplied with every reasonable safeguard such as gloves, tinted goggles, stools, mats and insulated telephones.

In addition to the personal element, there are mechanical features which enter into the proper design for personal and electrical safety, some of which are as follows:

All apparatus accessible from the ground should be protected by suitable enclosure and kept locked.

Equipment above ground should be on structures that render themselves extremely difficult to climb, except by persons properly equipped to ascend the structure.

Mechanical interlocking of apparatus so that the sequence of operation can only be the proper one as (with the operation of disconnecting switches connecting oil circuit breakers to lines on bus, it is advisable to have the circuit breakers so interlocked that it is impossible to operate the disconnecting switches unless the circuit breaker is open.)

Energized equipment should be insulated from mechanical or electrical hazard by location and isolation as far as reasonable.

All lines and equipment should be clearly and definitely named and marked.

Money spent for insulation of just a little higher value than is absolutely necessary, is money well spent.

Insulation values should be checked and maintained at the proper standard.

Structures should be checked periodically for loss of strength through corrosion or decay.

Proper replacement values should be determined and a definite maintenance schedule maintained.

Foreign hazards to transmission lines or stations should be removed or safeguarded as far as possible. These hazards may be from objects falling or being blown across the lines or substation or fire hazards. They may be either of your own equipment or the property of other parties adjacent to the station or lines involved.

Public thoroughfares and points generally accessible to the public should be avoided where possible. There is, ordinarily, hazard to service in such locations that should be avoided. There is also some additional hazard to the public. If equipment must, of necessity, be placed on these locations, it should be of the highest mechanical and electrical standard prevailing on the system.

Careful selection of the proper fire fighting equipment should be made and installation at all stations should be made adequate, especially where any quantity of oil is involved such as in high voltage circuit breakers and transformers. The location of this fire fighting equipment is important in that it should always be available under any fire condition.

Lines or equipment should be properly placed and spaced to allow for their safe maintenance or repair.

All units of equipment should be standardized as far as possible to allow for the maximum of common use of any unit quickly under emergency condition and to allow for the minimum of the stock required for maintenance and replacement.

There should be sufficient auxiliary equipment dependent on the importance of the service. This equipment should be quickly available for service in the event of failure of some of the normal working equipment and would necessarily be of the nature of spare transformers, circuit breakers, or auxiliary bus.

There is another phase of high voltage operation that has not yet been touched in this paper, that of the automatic operation of stations. The art has not yet advanced to the point of full automatic operation for stations of any size, complication or importance and is at the present time being used only in the semi-automatic stage. The function of this station removes to a large degree certain of the human element but introduces another type of human element in the intelligent and careful inspection and maintenance of this automatic equipment. It will fuction properly as automatic equipment to just the extent that it is properly maintained. This subject covers such a broad field that, to enter into any details worth while, it should be made the subject of a paper itself.

You will note from the above that in the general operation that there is little that is theoretical. It for the most part is the common sense solution of the problem as it arises and the careful studied attention to details.

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*Application of Tapered Roller Bearings on Roll Necks of Rolling Mills and Pinion Stands**

By FRED WALDORF†,

NO recent innovation in the steel mill industry has proven itself such a boon as the advent of anti-friction bearings for roll necks.

It has opened up a lane that will safely guide the mill owner through the mire of excessive power costs, and it will enable him to reduce his maintenance and repair costs as well.

Indeed greater benefits will accrue in that he will be able to produce a better grade of product, and at the same time increase his output just in proportion as the anti-friction bearings will prolong the interval between shutdowns for repairs, and in the case where idle rolls appear in mills, prolong the interval between roll dressings. Experience has demonstrated that where an idle roll running on plain bearings must be started by traction there exists a tendency to score or flatten the surface of the roll, which tendency to a large degree disappears when anti-frictions are used on the roll necks.

Savings in power as high as 60 per cent have been obtained through the use of our bearings in rolling mills, 140 per cent longer production has been realized in one instance and such covetous ambitions as cutting the maintenance and repair costs to the bone are now possible of realization.

The Timken Roller Bearing Company has played no small part in the efforts that have been put forth by the anti-friction industry to produce bearings that will stand the severe tests imposed upon them. In the majority of cases results far beyond the expectations of the most sanguine of those who have pinned their faith to the possibilities of the problem have been produced.

*To be Presented at Annual Convention, June 13th to 18th, 1927, Pittsburgh, Pa.

†District Manager, Steel Mill Division The Timken Roller Bearing Co., Canton, O.

It is therefore with extreme pleasure that we submit to the members of the A. I. & S. E. E. the results of our tests, and while we do not have a tremendous amount of data to offer at this time, it is hoped that what we have will lend assurance to you guardians of the power and maintenance accounts that the day is at hand when your fondest hopes can come to fruition.

About three years ago our company decided to design and build bearings for roll neck applications. A policy was adopted not to market any of these bearings until they had been thoroughly tested and

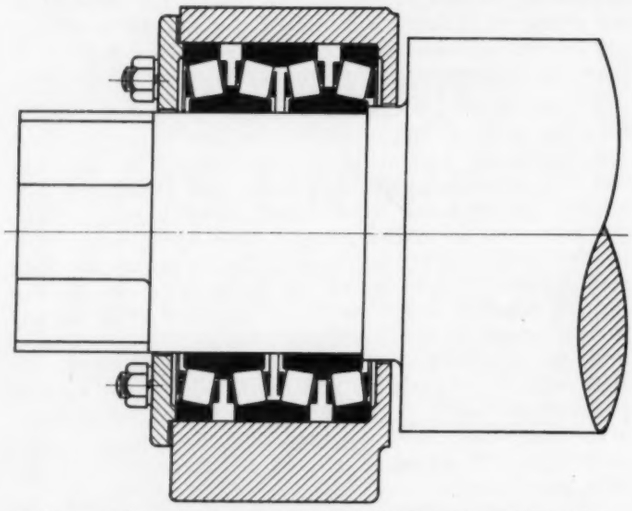


Fig. 1—Original 22″ Mill Roll Neck Bearing Mounting.

had definitely proven their adaptability in this type of work. Consequently, it was decided to change over one of the mills at the Timken plant and run a series of exhaustive tests to determine the exact requirements of the bearing equipment and installation.

A Three High 22″ Bar Mill Roughing Stand which is used to roll alloy steel, starting with a bloom of about 8″x9″ and reducing it to about 4″x4″ in seven passes was selected. Bearings were applied to the middle roll only. To meet the existing space available a bearing with a 13½″ diameter bore and 21″ outside diameter was designed. This bearing was mounted on the neck of the middle roll as shown in Figure 1 and the mill was placed in service on March 3, 1925.

The mill operates at a speed of 60 r. p. m. and the bearing used is rated at 400,000 pounds radial load at this speed. After rolling about 5,000 gross tons, the bearings were removed for inspection and found to be in good condition. It was then decided to reduce the capacity of the bearings and run further tests. This was accomplished by removing two rows of rollers from each bearing and on May 10, 1925, the middle roll was replaced in the stand with the bearings on the neck mounted as shown in Figure 2.

The capacity of the bearings was therefore reduced to 200,000 pounds radial load at 60 r. p. m. The bearings were removed for inspection several times between the 10th of May and the middle of September and found to be in good condition.

During the time the half bearing as shown in Figure 2 was in operation and after about 20,000 tons of steel had been rolled, a cold test was run on the mill. That is, the temperature of the steel was reduced to a point where something in the system would give way due to the excessive load. Our ordinary rolling temperature on this mill ranges from 2100 to 2200 degrees Fahrenheit. During the cold test the temperature of the blooms was continually dropped until a temperature of about 1450 to 1500 degrees was reached. At this point the motor crab broke and the mill stopped.

To determine the load to which the bearings were subjected, a Brinell test was made during the Cold Test. The equipment used to make this test consisted of two .30 to .40 Carbon steel plates 5″x4″x½″. These plates had both faces ground smooth. Also, two hardened plates 5″x4″x¾″ with spherical recesses ¼″ deep spaced to hold four 1″ diameter balls were used. The mill screws were loosened, the breaker blocks removed and the recessed plates placed in holders on top of the top roll rider. The balls were placed in the recesses, the impression plate placed on the balls and the mill screws run down and tightened. In this way the impression plate on top of the balls received the Brinell impressions from the balls caused by the spreading of the rolls when the cooled bloom passed through the mill. The impression plates were then removed and the same diameter impressions duplicated on the Olsen testing machine. The load required to make each of the duplicate impressions multiplied by the number of impressions on each plate gave the load per roll neck and therefore the load on each bearing. In this case it was found that the load on the roughing end of the

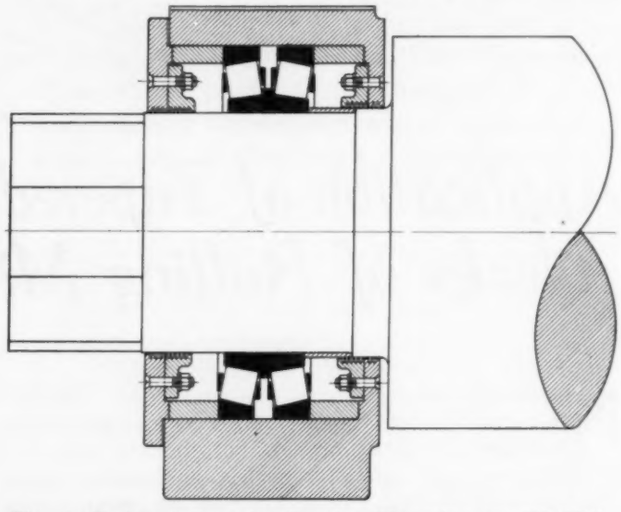


Fig. 2—Reduced Capacity Bearing Mounting on 22″ Mill.

roll was 658,800 pounds and the load on the finishing end 415,750 pounds.

Upon failure of the motor crab the roughing stand was torn down and the middle roll removed to determine what effect, if any, the load while rolling the cold steel had on the bearing. The bearings were found to be in excellent condition and no impression whatever could be discovered on any of the rolls or races. It will be remembered that each bearing had a rated capacity of 200,000 pounds and therefore operated respectively under shock load conditions of approximately 330 per cent and 200 per cent of their rated capacity.

The splendid showing of these bearings under the severe operating conditions prompted us to run tests with still further reduced bearing capacity. There were originally 27 rolls per cage, making a total of 54 rolls in the two rows of the half bearings. Now, every third roll in each cage was removed and the bearings were again placed in service on January 4, 1926. After rolling a total of 6,559 gross tons of steel the bearings failed on February 10, 1926. It is believed that if, when removing every third roll, a new cage had been made up to permit of evenly spacing the remaining rolls, the bearings would have had a much longer life. The bearings were then replaced with cages having complete sets of rolls and mounted as in Figure 2 and rolling was continued until over 40,000 gross tons of steel had been rolled by the mill.

The first completely equipped stand was placed in operation on March 25, 1926. This consisted of the 16" roughing stand with bearings on all three rolls applied similar to mounting shown in Figure 3.

The bearings used are 10" diameter bore and 14" outside diameter and have a rated capacity of 73,000 pounds at 100 r. p. m. On April 15 the rolls were removed for redressing. The bearings were inspected and found in perfect condition. On May 10 our bearings were reinstalled and after thirty days were again removed for redressing of the rolls. Again the bearings were found in perfect condition. To this date these same bearings are in service rolling on an average of 60 to 70 tons of alloy steel per day and working continuously at 30 per cent overload.

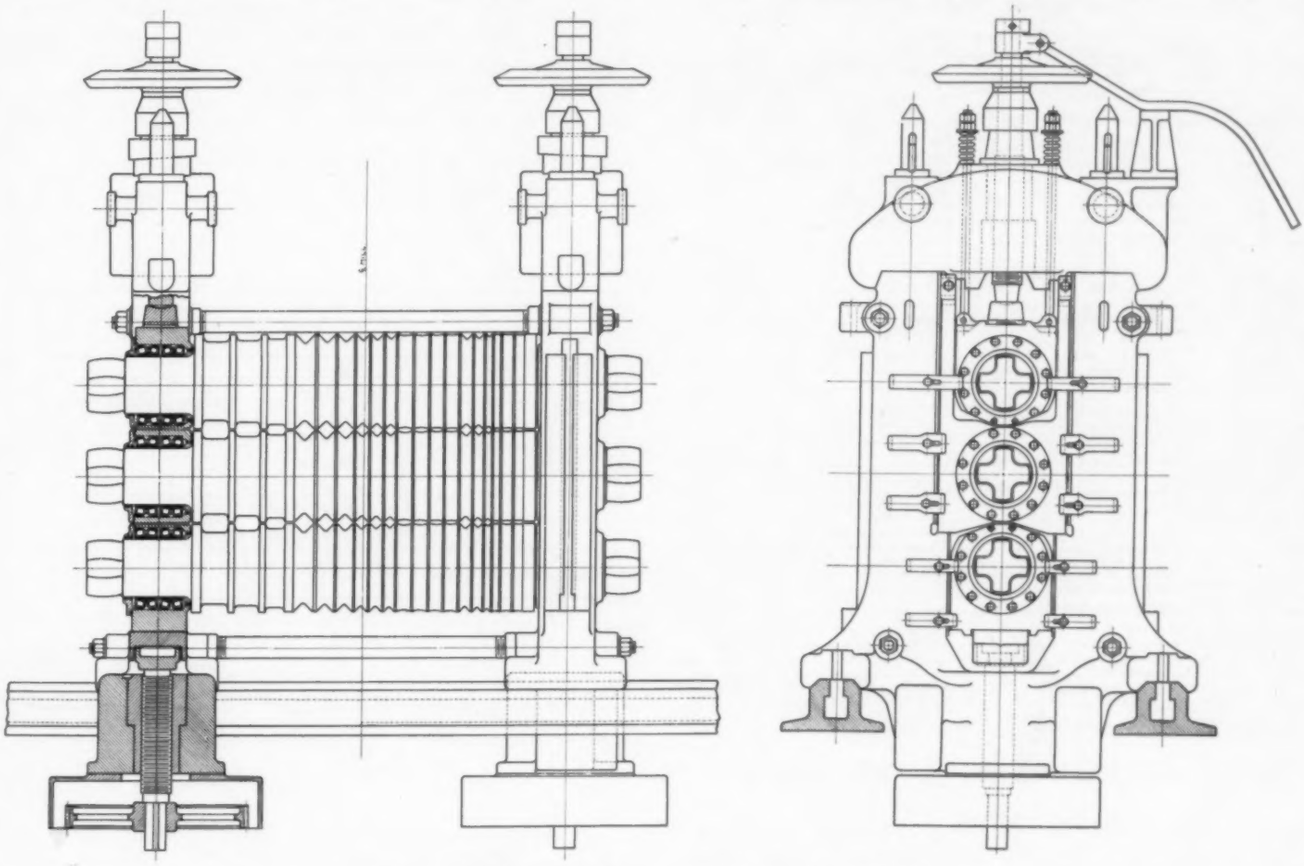


Fig. 3—Timken Bearings in 3 High 16" Bar Mill.

The above test assured us that our bearings would answer all of the load requirements which this type of service would impose upon them. Before starting our sales efforts on the bearings we desired, however, to determine also the power saving which might be obtained from an application. We were fortunate in having in our plant a Three High 16" Bar Mill which is a break down mill used in connection with our 12" and 10" Belgium type Rod Mills. This mill is individually driven by an 800 H.P. motor and is used to reduce 3"x3" alloy steel billets to sections about 2½"x1" oval. This mill offered an opportunity for making extensive power tests and we decided to make the necessary changes to put our bearings on the roll necks.

Testing on this mill was started on February 15, 1926, with plain bearings on the necks. From that date until May 11th tests were made every day on all sizes of billets rolled. It should be noted that the testing did not cover one continuous period of operation on plain bearings and then one o our own roller bearings, but testing was done first on plain bearings, then on our own roller bearings; again on plain bearings and last on our own roller bearings. The conditions encountered were therefore such as to eliminate any possibility of a material change affecting our readings. Another interesting point, is that our own roller bearings were placed under test without allowing any time for "running them in."

In making the test no changes were made in the mill except the substitution of our own roller bear-

ings for plain bearings on the roll necks. The pinion stand and all other parts were mounted on plain bearings. Also, power readings were taken only on the 800 H.P. 450 to 750 r. p. m. variable speed motor which drives this mill. Power consumption of the motor was measured by means of a recording wattmeter. The wattmeter was not disturbed during the entire length of the test. The length of every billet was measured as it was removed from the furnace. The temperature of each billet was determined by an optical pyrometer at the time the billet was being measured. The speed of the motor was taken by a tachometer and the roll speed determined from the reduction in the gear drive. Friction load power readings were obtained for each

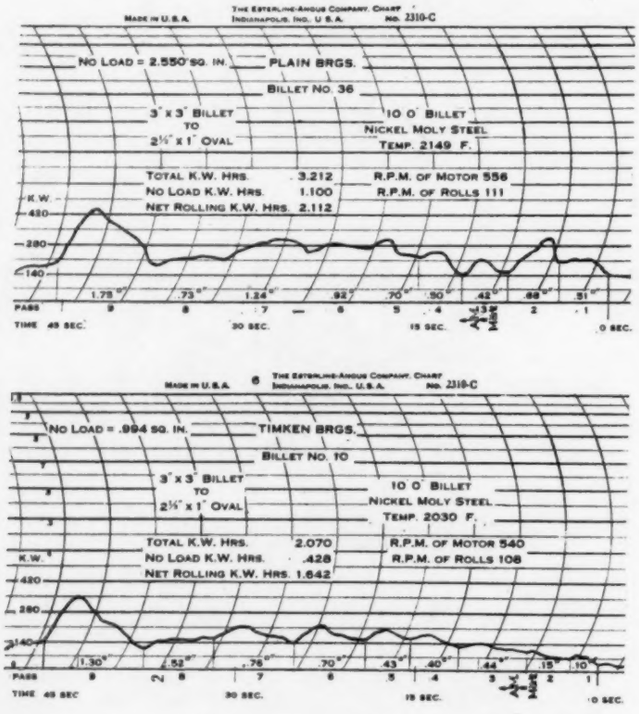


Fig. 4—Typical Wattmeter Reading Curve—Total Load.

billet. The power curves were measured by means of a planimeter. Results were brought down to a common basis by calculating the power consumption on the different billets in terms of kilowatt hours per foot of billet. Power consumption was calculated for three different conditions:

1. Total Operating Power Consumption, typical wattmeter reading of which is shown in Figure 4.
2. Friction Load Power Consumption, which represents the power required to drive mill idle. A typical wattmeter reading is shown in Figure 5.
3. Net Rolling Power Consumption, which is the difference between the total power consumption and the friction load power consumption.

Table No. 1 shows the most extended test we were fortunate in making as it covered a total of 77 similar billets. Forty-six of these billets were rolled on plain bearings and 31 on Timken Bearings. Table No. 2 shows another test in which 27 billets were rolled. Ten of these were rolled on plain bearings and 17 on Timken Bearings. The percentages of saving effected by our roller bearings are clearly shown.

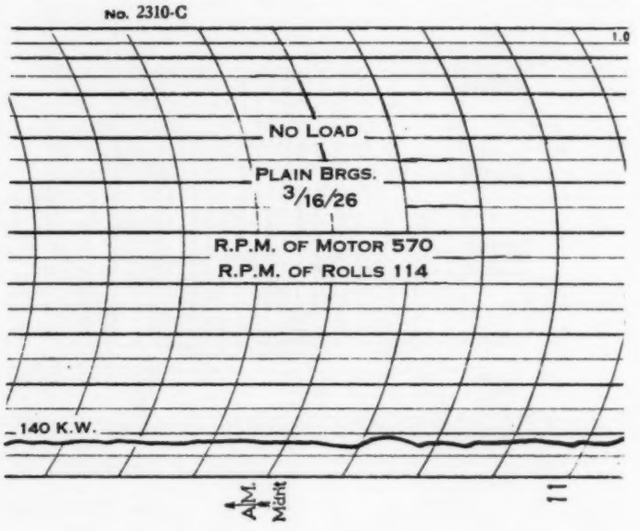
AVERAGE RESULTS

(Table No. 1)

Size of Billet	3"x3"
Size of Final Section	2½"x1" oval
Square Inches of Reduction	7.02
Steel	Nickel Moly.

	Plain	Timken
Total Number of Billets	46	31
Temp. Degrees F.	2167	2091
R. P. M.	547	529
Max. K. W.	484	282
Total Kw. Hrs. Per Ft. of Billet	.3108	.1910
No. Load Kw. Hrs. Per Ft. of Billet	.1061	.0570
Net Rolling Kw. Hrs. Per Ft. of Billet	.2047	.1340

Per Cent Saving Affected by Timken Bearings	
Total Operating Load	38.6
Friction Load	46.3
Net Rolling Load	34.6



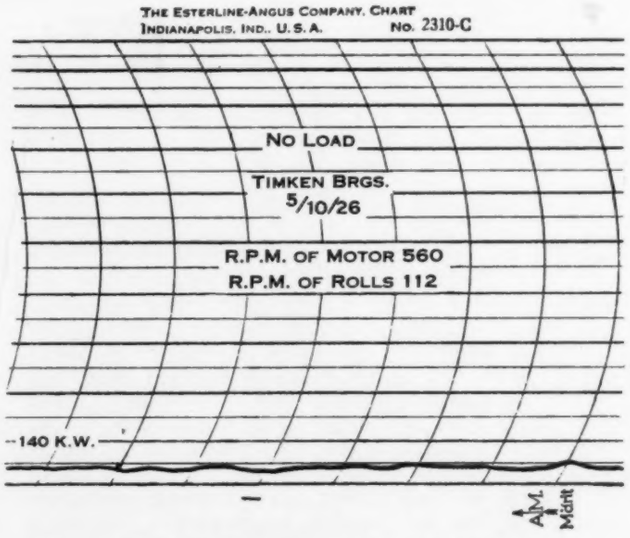


Fig. 5—Typical Wattmeter Curve—Friction Load

AVERAGE RESULTS

(Table No. 2)

Size of Billet	1⅞"x1⅞"
Size of Final Section	1¾"x⅝" oval
Square Inches of Reduction	2.52
Steel	Nickel Moly.

	Plain	Timken
Total Number of Billets	10	17
Temp. Degrees F.	2176	2060
R. P. M.	558	568
Max. K. W.	299	176
Total Kw. Hrs. Per Ft. of Billet	.2724	.1314
No. Load Kw. Hrs. Per Ft. of Billet	.1092	.0440
Net Rolling Kw. Hrs. Per Ft. of Billet	.1632	.0874

Per Cent Saving Affected by Timken Bearings	
Total Operating Load	51.8
Friction Load	59.8
Net Rolling Load	46.5

(Table No. 3)

Table Showing Power Saving Affected by the Use of Timken Bearings on Roll Necks of Timken 16", Three High, Roughing Stand:

Size of Billet	Size of Final Sect.	Steel	Total Load	Per Cent Savings Friction Load	Net Rolling Load
3"x3"	2½"x1" oval	Nickel Moly.	38.6	46.3	34.6
3"x3"	2½"x1" "	1.25% Nickel	60.3	56.2	62.9
2½"x2½"	2½"x1" "	3.5% Nickel	37.8	40.2	36.5
2½"x2½"	2½"x1" "	1.25% Nickel	52.8	63.6	47.2
2"x2"	1¾"x⅝" "	3.5% Nickel	37.9	39.4	36.7
1⅞"x1⅞"	1¾"x⅝" "	Nickel Moly.	51.8	59.8	46.5

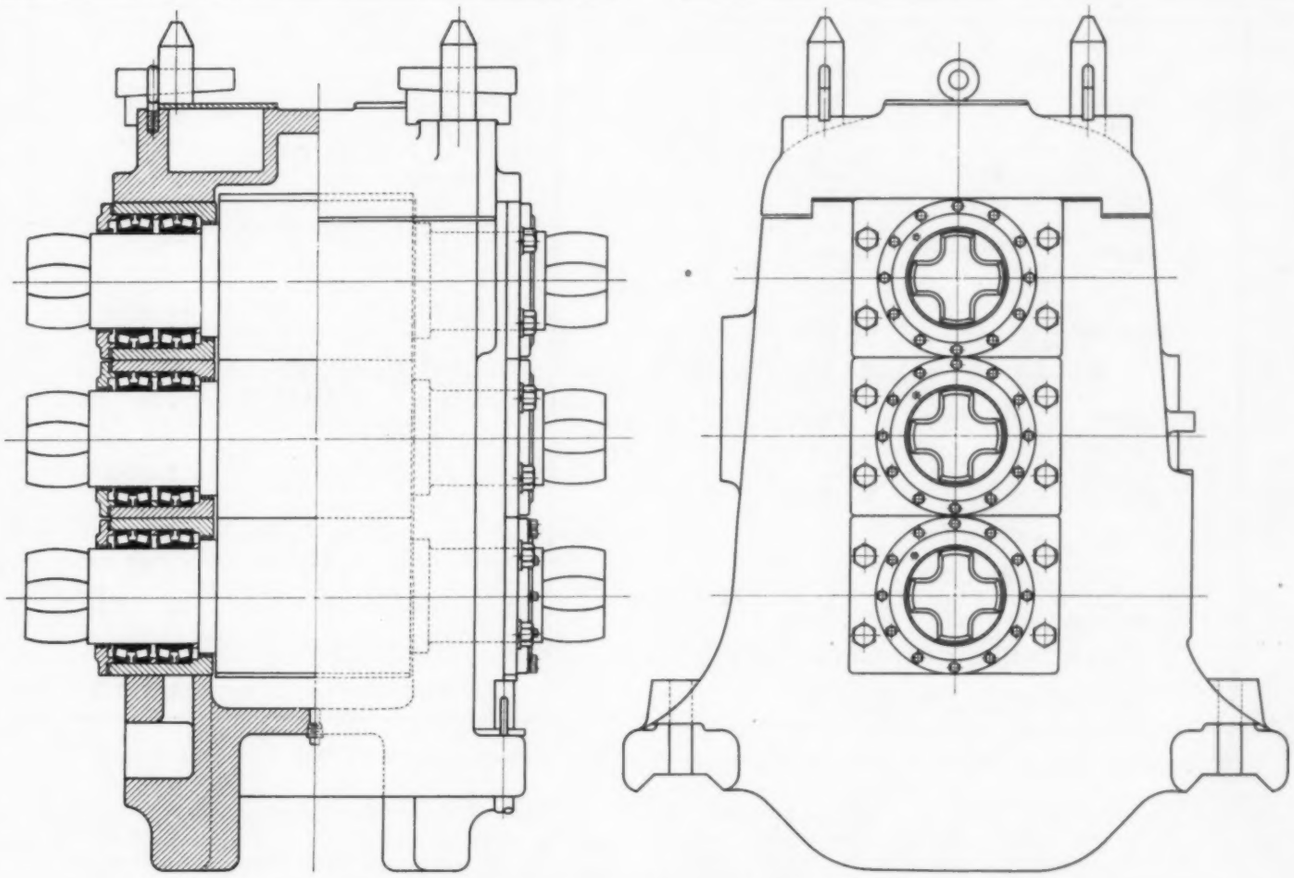


Fig. 6—Pinion Stand for Three High 16" Bar Mill.

The complete test covered a total of 279 billets, varying in size from 3¾" square down to 1⅞" square. Steel of various analyses were rolled and wherever possible tests were made on both plain and our own roller bearings when rolling the same section and analysis. Of the 279 billets used, 160 were of section and analysis that had been rolled with both plain and our own roller bearings. The remaining 119 billets were of section and analysis that were not rolled during the time both our own roller and plain bearings were used.

Table 3 Summary of Test Showing Power Savings Obtained.

Table 3 shows the power savings effected on the 160 billets which could be compared.

The results tabulated above conclusively show the possibility of very considerable savings in power by the use of roller bearings on the roll necks. The figures showing the percentage of savings in power may not be exactly duplicated in another mill rolling different sections, but it is quite safe to conclude that a power saving of 30 per cent to 50 per

cent can be made by the use of roller bearings in place of plain bearings on the roll necks.

Figure 6 shows the application of roller bearings on the pinion stand of a Three High 16" mill. The pinion stand, of the 16" mill above reported on, has now been equipped with roller bearings as shown in Figure 6, and placed in operation on March 10, 1927. A series of tests were immediately started on billets of same section and analysis previously rolled to determine additional savings obtained by the substitution of roller bearings for plain bearings on the roll necks of this pinion stand. The bearings used are the same as those used on the roll necks of the mill. As soon as a sufficient number of readings are obtained the results will be computed and published.

Having definitely established the adaptability of roller bearings on roll necks and the consequent power savings derived, the Timken Roller Bearing Company began to make studies of the general application of bearings in this type of equipment. In

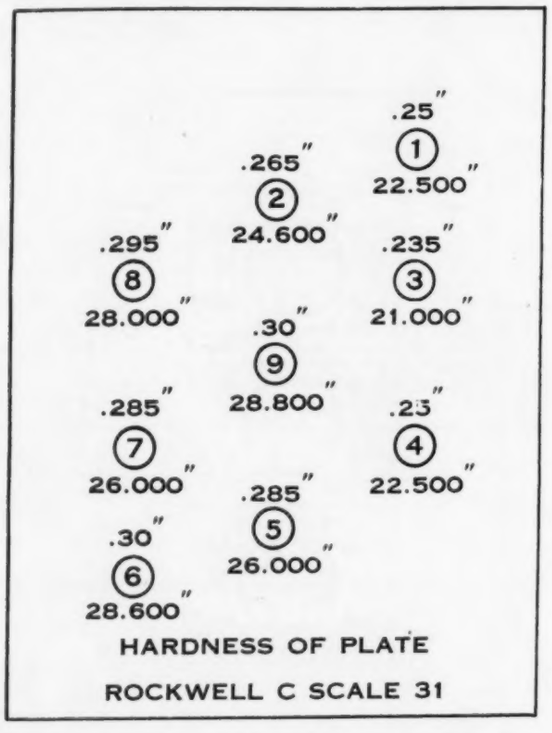


Fig. 7—Drive Side of Mill Roll Neck Brinell Plate.

order to have complete information of the bearing capacity required for each individual job studied, thorough and complete Brinell tests, similar to the one previously described in connection with our own 22" mill, were made. These tests have been made on various sizes of hot and cold steel rolling mills and zinc mills and from the Brinell plates, similar to those shown in Figure 7 and 8, complete information on the roll neck pressures encountered in these mills has been obtained.

Impression No.	Diameter of Impression	Lbs. to Duplicate Impression
1	.25"	22,500
2	.265"	24,600
3	.235"	21,000
4	.25"	22,500
5	.285"	26,000
6	.30"	28,600
7	.285"	26,000
8	.295"	28,000
9	.30"	28,800
	Total Load—	228,000

Impression No.	Diameter of Impression	Lbs. to Duplicate Impression
1	.21"	18,000
2	.185"	12,000
3	.24"	21,500
4	.255"	23,000
5	.24"	21,000
6	.255"	23,000
7	.24"	21,000
8	.25"	22,000
9	.19"	12,500
10	.23"	19,000
	Total Load—	193,000

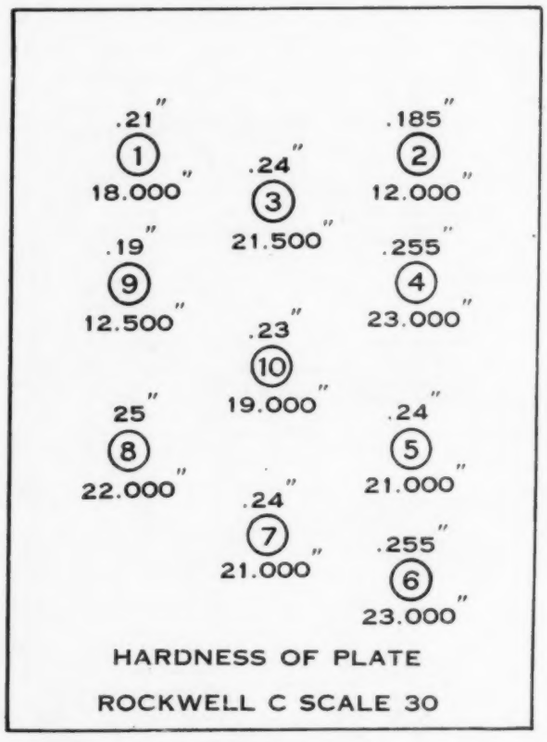


Fig. 8—Outside of Mill Roll Neck Brinell Plate.

With this information it has been comparatively easy to select bearings with the desired factor of safety for long and satisfactory operation.

Up to the time of writing this paper there have been installed and placed in operation the following mills:

1. A Two High 18"x36" cold strip mill with roller bearings on the main roll neck and on the pinion stand. These bearings are 10" diameter bore by 15¾" outside diameter and have a radial load carrying capacity of 130,000 pounds at 100 r.p.m.
2. Four Cluster Mills for cold rolling strip steel in widths up to 30". Roller bearings are installed on the necks of the backing-up rolls. The bearings on the back-up roll necks are 12" diameter bore by 19½" outside diameter and have a radial

load carrying capacity of 450,000 pounds each at a speed of 50 r. p. m. A recent test on this mill while rolling 14⅛" wide strips with a draught of .035 showed a power saving of about 60 per cent over the plain bearing mills on similar work.

3. Six stands of Four High mills for rolling cold strip sheets up to 36" wide. The bearings are installed on the necks of the backing-up rolls and are of 17" diameter bore by 26½" outside diameter. Each bearing has a rated radial capacity of 875,000 pounds at an operating speed of 50 r. p. m.
4. Four stands of Four High cold rolling mills for rolling strip steel. Bearings on these mills are also used on the necks of the backing-up rolls and have a rated radial capacity of 875,000 pounds at a speed of 50 r. p. m. The bearings are also 17" diameter bore and 26½" outside diameter.
5. Three stands of a 52" Universal Beam Mill rolling wide flanged I-Beam and column sections. The bearings are mounted in the vertical rolls of this mill. They are of a 12½" diameter bore by 25½" outside diameter and have a rated radial capacity of 1,600,000 pounds at a speed of 100 r. p. m.
6. A 22" Three High Roughing Stand rolling alloy steel 8"x9" blooms down to 4"x4" billets.
7. A 16" Three High Bar Mill and pinion stand rolling 3"x3" alloy steel billets down to 2½"x1" oval. The last two mills are the subject of this paper.
8. In smaller mill installations we have furnished bearings for,

   Back rolls for wheel rolling machine, four 7"x14" single bearings per back roll, taking loads from 150,000 pounds at 100 r. p. m. to 200,000 pounds at 50 r. p. m.

   13" pinion stand for a 3-high copper rod mill, twelve 5⅞"x10" single bearings. Exact load and speed not available.

   Six edging mills, three using 7" and three using 9" bearings on the roll ends of the spindles. The bearings on the other ends of the spindle being 5" and 7" respectively.

Power tests are continually being made on many applications. Brinell tests are being made on existing mills to determine the roll neck loads and a complete store of information is being gathered for further successful applications, a large number of which are now in the process of design on various sizes of hot and cold rolling mills.

Careful study has also been given to lubrication problems. A number of different types of lubricant have been analyzed and placed in test. These tests will be further continued to obtain other types of lubricants which will answer all the severe requirements encountered.

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*Bearings For Use In Rolling Mills**

By C. J. KLEIN†

BEARINGS used in connection with Rolling Mills and auxiliary equipment have received more thought in the way of proper application and design than any other single item in the construction of this type of equipment, especially so within the last decade. This is mainly due to the fact that approximately 30% to 60% of the power expended by the motor or engine is lost in bearing friction, depending on the application. Another item of considerable cost is the lubricant and additional provisions have been made from time to time for collecting and returning the oil to the supply reservoir.

The use of roller bearings has been steadily increasing until at the present time about 60% of the bearings in rolling mill auxiliary equipment are roller type. This has been brought about through various factors. The outstanding feature of roller bearings is the large saving in power; for instance, it has been found that a large percentage of the power required for rolling hot strip steel in bronze bushed with babbitted insert bearings is wasted in journal friction, while the friction of a roller bearing is practically nil. Due to quantity production on roller bearings up to about 7" diameter, the cost of same has been reduced to such a point whereby the total installation cost of a roller bearing is practically the same as bronze or babbitt bearing. The efficient means of lubricating roller bearings is also an item in favor of their use.

The simplicity of design in the mounting of roller bearings which has been attained is also worthy of note. Roller or ball bearings have not been used extensively for taking thrusts as the ordinary bronze disc will usually answer the purpose and simplify the design. Ball bearings have not been used to a great extent in the rolling mill game on account of their limitations in load carrying capacities.

The design in mill roll bearings used for Blooming, Plate, Universal, Billet, Bar, Merchant and Sheet Mills have undergone very little change up to the present time.

As the bearing pressures run very high on bearings of this type, grease is invariably used for the lubricant. Bronze bushed bearings have been recently designed for continuous oil lubrication but no data is at hand on the operation of same.

The materials now in use for mill roll bearings are Babbitt in a great variety of analyses, Babbitt with bronze strip inserts, Brass or Bronze of various combinations, Brass or Bronze with babbitted inserts. Due to the fact that roll journals are limited to both diameter and length, diameter which must be necessarily large in comparison with the body diameter of the rolls on account of getting the maximum bear-

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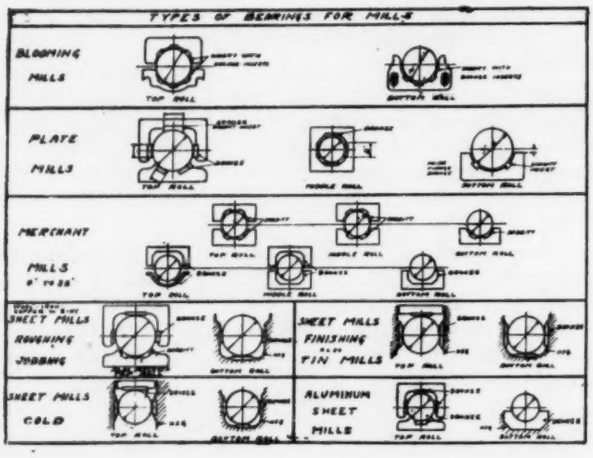
†Engr. Dept., United Engineering & Foundry Co., Pittsburgh, Pa.

ing area possible and also on account of strength and length for the reason that a long journal causes greater stresses when it bears on its outer edge, thereby causing considerable roll breakage, oil lubricated and roller bearings have not come into their own for this class of service.

The following diagrammatical sketches will give an idea of the different mountings of mill roll bearings:

Mill pinion bearings have undergone considerably more changes in the way of improvement than the bearings of the rolls which they drive. This type of bearing is also limited in the way of design due to the fact that the distance between the bearings is



FIGS. 1 and 2 show some of the typical bearing arrangements as used on mill roll necks. As will be noted, there is quite a variety of mountings for doing practically the same kind of work and this is due partly to the operators becoming familiar with a certain type and wanting it duplicated.

very small compared to the size. The design of these bearings, as used in the early stages of the rolling mill game, consisted of babbitted, cast iron shells with large cored pockets in same for the storing of grease for the lubrication of the journals. Ordinarily, housings and bearings were of different design than the roll stand but there are any number of applications where roll housings were used to support the pinions. With the above type of bearings, the pinions were lubricated with tar or gear shield which was applied directly to the teeth. Lugs were cast on the housings for supporting boards which formed a guard around the pinions. Babbitted surfaces are provided on the ends of the bearings for taking care of the thrust. No provisions were made for the collecting of the overflow grease. With cast tooth gears, this type of bearing operated satisfactorily.

However, with the inception of cut tooth pinions, more accurate mounting of the pinions was necessary; also more efficient means of lubrication. It was the consensus of opinion, and quite naturally so at that time, that a heavy oil or gear shield was necessary for the pinion tooth lubrication and a lighter oil for the bearings. This condition necessitated a design for the keeping of the two lubricants separate which was by no means an easy task. This method of lubricating also meant two pump systems as the oils were ordinarily collected in different compartments at the bottom of the pinion housing and returned to central cleaning, cooling and pumping units. Bearings of this type were also provided with wipers and oil catchers on the outer ends for collecting the oil getting beyond the bearing surfaces. While the respective diameters of bearings for the different pitch diameter pinions were maintained approximately the same as for grease lubricated journals, they were increased very materially in length. This was necessitated by the fact that the oil lubricated bearings would not carry the equivalent loads of grease lubricated bearings. The ordinary proportion of the length of oil lubricated mill pinion bearings is about one and one-half times the diameter of the bearing. On account of the difficulties as before mentioned, the oil refiners have provided oils which can be used for the lubrication of pinion teeth as well as the journals which carry the pinions. The use of single oiling lubrication simplifies the design of bearings to a very great extent and also saves about ten to twelve inches of the length of the pinions. The usual mounting of pinion bearings is in machined windows of the housings. The shells for the bearings of each end of the pinions can be made in one piece or split in as many pieces as there are pinions. Another type of pinion housing in use at different times is the layer type of housing which is split on the centerline of the bearings. With this type of housing more bolts are usually required than with the window type which ordinarily has only four cap bolts. Having removed the four cap bolt nuts or keys, all pinions are ready to be removed. While the duty of a mill pinion bearing is severe in the way of loads, these are practically all intermittent and the peripheral speeds at which they run being rather low, there is comparatively little trouble encountered. Where the speeds get high and the loads heavy and continuous, special precautions should be taken in providing ample bearing surfaces and abundant oil which should preferably be received from a central system provided for the cooling and cleaning of the oil. Conditions of the above mentioned type are encountered in driving looping rod mills, small continuous and looping strip and merchant mills. Babbitt is used for the bearing metal on

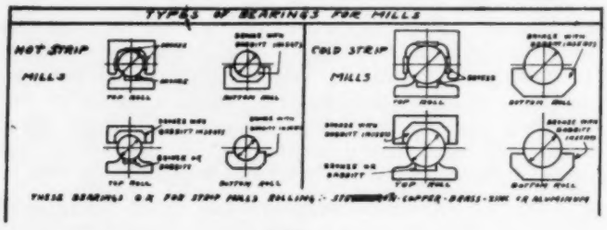


FIG. 2.

practically all applications. On some small merchant mills bronze has been used, but this is not the general custom. Roller bearings have not come into their own for pinion bearing applications and this is due primarily to the limited amount of space available from center to center of bearings. By the elimination of the inner race of the roller bearings, it is possible to mount a roller bearing on a shaft of approximately the same diameter as would be used with a babbitted bearing but this necessitates a very hard journal surface which is costly and difficult to obtain.

Chain or ring oil bearings are not possible on account of the close bearing centers. The two follow-

ing cuts will give an idea of the old style grease lubricated journal and an up-to-date arrangement designed for double oiling lubrication but operated as a single oiling system by making a few changes in the pipe connections.

Drive and flywheel unit bearings have also come in for their share of improvement. Due to the comparatively high loads and speeds at which motor pinion bearings operate, they have been made of the ring or chain oiling type with an oil reservoir underneath the shaft or a continuous feed type or a combination of both. Very elaborate designs have been worked up where excessively high speeds and loads are encountered such as on overhung flywheel pinion shafts. Bearings of the ball and socket, ring, or force feed oil lubricated, water cooled type, have proved to be the most effective. This type of bearing until recently has been designed for the use of a different lubricant on the pinion teeth than in the bearings. With the advent of a lubricant that could be used for both pinion teeth and journals complications encountered in the design of oil catchers were eliminated. This was of greater importance in the design of the pinion than would be anticipated due to the fact that the centers of bearings could be

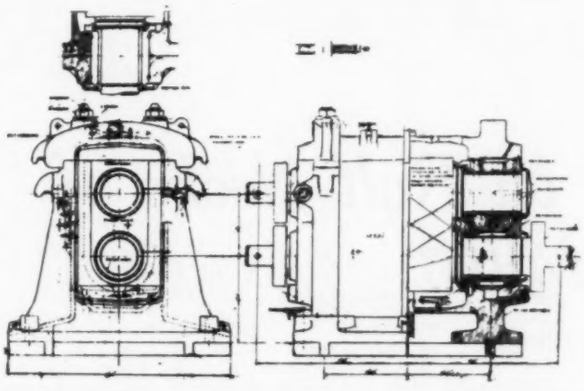


FIG. 3—Typical arrangement of an up-to-date pinion stand.

decreased about ten to twelve inches which is of great importance in the elimination of shaft deflection. The question would naturally be asked—why not increase the shaft diameter to eliminate this shaft deflection? In some cases this is possible without any detriment to the design, but when speeds are high and large gear reductions are required; it is essential to keep the pitch diameter of the pinion as small as possible which, in turn, limits the shaft diameter. Also, it is advisable to keep the peripheral speed of shaft in the journal as low as possible. The ordinary proportion of high speed bearing lengths is from two to three times the diameter. Babbitt—in varying grades, is used for the bearing surface of high speed heavy duty bearings. Replaceable shells are provided in most designs where babbitt is used so that spare babbitted shells can be put in without long shutdowns. Intermediate bearings for double reduction drives must be designed to withstand tooth loads caused by the motor gear as well as the intermediate pinion as both loads react in the same direction. When bearings carrying flywheels and taking tooth load become too heavily loaded with the combined load, it is usually possible to reverse the tooth pressure upward or in other words run the pinion over, thereby tending to equalize the running conditions of the bearings. Care must be taken, when running pinions over, to subtract all projected areas of holes and slots from the total projected area. This condition may run a bearing pressure 20% higher than if the loads were all down.

Roller bearings for drives of the above character have been used from time to time in a small way, but not until recently have they come on the mar-

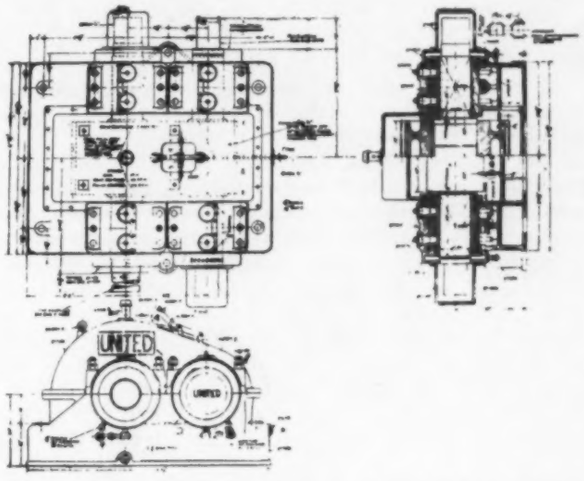


FIG. 4—This is one of a large number of drives being built for driving hot strip mills. Note the massive construction and liberal bearing and gear sizes which will give long life to the wearing parts.

ket as a standard product. Back in 1914 "United" built a 1400 H.P. Drive for a 21" Merchant Mill for the Union Rolling Mill Company, Cleveland, Ohio, which had roller bearings for the pinion and flywheel shafts. The flywheel was mounted between two bearings. This was quite a departure from the babbitted bearing but proved very satisfactory in service and is still in operation.

One objection that is raised in connection with overhung flywheels is the necessity of removing a

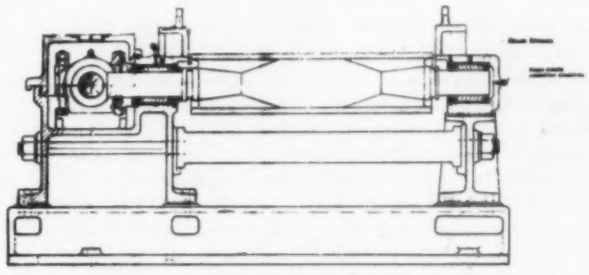


FIG. 5—Illustration shows simplified construction of roller bearing application.

flywheel in case a bearing goes bad. While this possibility is remote, it still exists. Simplicity of lubrication on moderate size roller bearing drives is something worthy of consideration. Gears can run in oil and bearings can be grease lubricated through a pressure system. Quarter box bearings were used to a great extent on main gear bearings when drives for reducing motor speeds to mill speeds were first used. This was due, mainly, to the fact that mechanics were familiar with that type of bearing on

engines. Circular shell bearings are now used on practically all main bearings.

Bearings for carrying lay shafts, bevel gears for driving tandem mill, extension shafts, etc., are usually of the ring or chain oil, babbitted, shell type. Where the speed of the shaft is not sufficient to use rings, a circulating system is used. As bearings of this type are usually far enough apart to be mounted on separate concrete piers, it is advisable to make provision for shimming in case of the pier settling.

The following illustrations will show a few of the most typical designs of bearings which have been used and are still in service.

Bearings for mill tables and auxiliary table conveyors probably offer the greatest variety of design and use of materials. Table roller bearings, as used in the Rolling Mill Industry, vary approximately from one and one-half inches to nine inches in diameter and in lengths up to about twenty inches. Some of the types of lubrication are chain or ring oil with or without a circulating system which maintains a fixed level in the reservoir, oil lubricated through wick feed, force or gravity feed, or cotton waste. Grease lubricated from a central forced feed system or individual fittings for filling reservoir from a grease gun, or grease pockets, which are filled by a paddle through a large opening in the cap. Splash lubrication proves very satisfactory where the speed of the drive gears is sufficient to throw the oil which is collected in troughs and returned to the bearing reservoir. Bearing mountings and materials of a large variety are in service, of which the following are worthy of mention—bronze or babbit, ring or chain oiled, mounted in pillow blocks or supports cast integral with the girders. Roller type of the solid, hollow or tapered roller variety. Ball and socket, as well as straight seat supports, have been used. Die cast babbitt shells have also been used successfully. Ball bearings are used on light tables and have the advantage of taking very little space.

The prejudice, which the mill operator has against using roller bearings for table line shafts, is gradually being eliminated. The objection to this type of bearing was the fact that three to six mitre gears had to be removed in order to get off a bearing. With the type of bearing that is being built, replacements are few and far between.

With the up-to-date type of table, equipped with roller bearings, it is possible to revolve twelve to fifteen rollers by taking a hold of the line shaft coupling, the leverage being about six inches and the bevel gear a one to one ratio.

The following illustrations will serve to illustrate a few of the most typical installations which are in use.

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*Anti-Friction Bearings on Roll Necks of Rolling Mills**

By E. C. GAINSBORG†

WHEN our company, was asked to contribute a paper on the practical application of anti-friction bearings, to roll necks of rolling mills, for discussion at the June meeting of the Association of Iron & Steel Electrical Engineers, we realized the difficulty of presenting specific data, because this question is still very much in the development stage.

Although there are installations which have been operating satisfactorily for limited periods of time, there are still many variables in the problem which make it impossible to apply the anti-friction bearing universally. Each individual application is a separate engneering problem, and must be solved as such; consequently to be safe, the development must not be forced, but must follow a proper systematic study of all conditions involved.

True that the substitution of anti-friction bearings for sleeve journals, on any type of equipment, offers certain very definite advantages. To get the most from their use, it is necessary to have a complete understanding of the problem. Satisfactory and successful operation is not limited by the type or size of bearing used; housing design, ease of installation and maintenance are all a part of the ultimate results.

The Steel Mill Division of our company is making a systematic survey of machinery used in the manufacture of steel. The program is not limited to any specific equipment, it covers all kinds of machines used.

As in number of units, next to electric motors, rolling mills predominate in the Steel Industry, it seems desirable to concentrate greater efforts at this time, on the study of applying anti-friction bearings on roll necks.

The design of plain bearing mills has been largely on the basis of "broadening out" from precedent to precedent. The proportioning of rolls, that is, the diameter and length of the barrels and roll necks are the result of established experience. Space limitations in rolling mills, particularly for changeover jobs, makes the problem a very difficult one for anti-friction bearings. Because the outside diameter of an anti-friction bearing is limited by the diameter of the barrel roll and the bore controlled by the roll neck diameter, made large to withstand heavy stresses, this offers no alternative as to the bore or outside dimensions of a bearing which may be used. This condition makes it very necessary that we have accurate data on rolling pressures, in order to determine the possibility of applying bearings of standard size, or the necessity of applying bearings of special dimensions to fit within the space limitations.

*To be Presented at Annual Convention, June 13th to 18th, 1927, Pittsburgh, Pa.

†Engineer SKF Industries, Inc., New York, N. Y.

Heretofore conventional method of obtaining journal pressures has been by using two flat plates, with a series of steel balls between them. This unit was inserted on top of the upper cap of upper roll housing and underneath the screw that bears against the breaker plate. As a result of pressure imposed, the balls would Brinnell the plates and from the diameter of ball impressions it is possible to determine the maximum load on that journal.

Though pressure readings obtained by that method may appear to be quite satisfactory, in reality they are not, because it gives the maximum or peak loads only, such peak loads may occur accidentally in the setting up, or otherwise. Anti-friction bearings are able to carry considerable overload, if it occurs infrequently and for a small duration of time. The useful life of anti-friction bearings, based on hours of service, can be approximately predetermined if speed and average load to which the bearings are subjected, are known.

In order to overcome the disadvantage of the ball indentation method, our Engineering Department has developed a device of simple design that can be used readily to obtain continuous journal pressure readings on either cold or hot rolling mills, with little or no interference with its production.

The design of this measuring unit is based on the "Strain Gauge Principle." It consists of two elements—

First: The part upon which the load is imposed.

Second: The part which indicates the imposed load.

The first part is a hardened steel cylinder of suitable dimensions, which is interposed between the loading screw and upper cap of bearing box. Under load, the cylinder will be elastically compressed and this compression is proportional with the load; therefore if the approach of two fixed points, on the cylinder, can be accurately measured, this in turn can be interpreted in terms of load applied to the cylinder.

A sensitive dial indicator, of special design, serves the required purpose; this indicator is attached at the fixed points on the cylinder, by means of clamps and lever mechanism.

To insure correct interpretation of the dial readings, the instrument may conveniently be calibrated under a Universal Testing Machine.

Due to space limitations, it was necessary to design the instrument correspondingly, which of necessity reduced its accuracy; the limit of error turned out to be 5% to 10% of the indicated load. This error, for practical purposes is negligible and can be disregarded when compared with the many indefinite variables that prevail, when an attempt is made to generalize the results.

The measuring device described has been used to determine journal pressures on a cold rolling strip mill and on a hot rolling merchant mill; both of these mills were of two high type. From the results obtained, we have been able to derive information and conclusions on the possible use of anti-friction bearings and a comprehensive understanding of journal pressures.

Our findings may be briefly summarized as follows:

Cold Rolling

In the rolling of cold strip, there exists a critical pressure below which no reductions can take place. This critical pressure varies with the hardness of the material, dimensions of roll and width of stock. It seems reasonable to assume that the load value corresponds to the yield point of the stock rolled.

A curve showing the relation between reduction in thickness and the corresponding journal pressures, indicates that the intensity of load is not directly proportional to the reduction. In other words, a comparatively great increase in reduction may be produced by a relatively small increase in journal pressure, once the yield point is transgressed.

The ultimate journal pressures that occur during the process of rolling may be divided into two parts:

First: Pressure required to overcome the yield point; this part of the load does not directly produce a reduction.

Second: Pressure required for actual reduction of stock—commonly referred to as draught.

Journal pressures vary directly with the width of stock rolled, so it follows that the wider the stock, the greater the journal pressure. This condition limits the possibility of applying anti-friction bearings of standard dimensions, when considered for change-over of plain bearing mills used for the rolling of stock of considerable width. On the other hand, there should be no difficulty of equipping change-over mills used for rolling stock of narrow width.

Hot Rolling

The potential value of anti-friction bearings if applied to two high, hot merchant mills, is reflected in a marked reduction in manufacturing cost, because of substantial power saving.

Test conducted on a mill, used for rolling stock of a section 1½"x⅜", mill operating at about 500 RPM showed that 30% to 40% of power imput was consumed in overcoming friction of plain bearings.

This exceedingly high ineffective power consumption, is traceable to the high speed of operation, heavy journal pressures and the duplication of journals at each end of the mill, in other words the separating force that occurs when stock is passed between the rolls, results in journal pressure at the roll necks of upper and lower rolls, which is the equivalent of duplicating the load.

Use of anti-friction bearings would make it unnecessary to have water cooled housings. If the housing be properly designed it should not be necessary to introduce or change the lubricant more often than at the termination of 100 to 150 hours of service.

Average pressures that occur on two high, hot merchant mills, indicate the values are well within the scope of the capacity of standard dimension bearings. Design of SKF spherical bearing should satisfy service requirements for this application admirably, because the bearing is a self contained, self aligning unit, it permits flexibility in the locating and adjusting of the rolls axially, when it is necessary to maintain the position of pass within a close degree of accuracy, as in form rolling, such as rounds; further the bearing inherently provides for any misalignment caused by deflection of rolls, without imposing undue strains at the roll necks.

There are certain outstanding advantages that the use of anti-friction bearings offer, which are not had in plain bearings; these are control of gauge thickness, brought about because of close tolerance to which ball and roller bearings are manufactured; speed of operation can be increased without undue heating, this is reflected in increased production; maintenance, insofar as lubrication is concerned can be had more effectively and at a lower cost.

Notwithstanding the advantages pointed out, from the mill man's point of view, considering it as a commercial proposition, the changeover of existing two high mills, for cold strip and hot rolling, is important. This problem must be given a great deal of thought by the manufacturer of anti-friction bearings, for it is only through the medium of changeover of plain mills that the advantages resulting from the use of their product can be demonstrated. Of course, it may be expected that the field for changeovers on cold roll two high mills, will be largely restricted by the dimension of rolls used with respect to width of strip and draught.

In contrast to changeover problems it is interesting to consider the possibilities of using anti-friction bearings on equipment of new design. For example, the "Four High" and "Cluster" mills, which are a modification of the two high mill. These designs inherently offer advantages for the use of anti-friction bearings, due to liberal space conditions.

A four high mill, as the name implies consists of four rolls mounted with the axis of rotation in the same vertical plane. Two center rolls, referred to as work rolls are of small diameter. They are supported on yokes of half bearings, the load imposed on them by the separating force, when the stock is passed through, is transmitted to two backup rolls located above and under them. The diameter of the backup rolls is much greater than that of the work rolls and sufficiently large to permit the use of anti-friction bearings of large dimensions, thereby furnishing ample carrying capacity.

A Cluster type mill consists of six rolls—two work rolls of small diameter, the same as on the four high mill and two backup rolls per work roll, set at an angle to the vertical axis of the work roll. The backup rolls on this type of mill are also of a diameter much greater than the diameter of the work rolls.

An additional advantage is had because the work rolls are of small diameter which requires less journal pressures, for a given draught.

In summing up the activities of our company, in connection with the development of the use of our product in the Steel Industry, it can be best described by outlining step by step, the procedure followed out and the policy that governs.

First: Information obtained by experience in this country and abroad, pertaining to the use of our bearings on steel mill machinery was collected and correlated.

Second: Careful study was made of existing successful applications, other than in the steel industry, but on equipment where service conditions in some phase approximate the requirements that exist in the operation of steel mill machinery.

Third: A survey was made of machinery used in the steel industry, with a view of becoming thoroughly acquainted with the characteristics of operation and service, also to determine to what extent anti-friction bearings may be used without necessitating change in design of steel mill equipment or resorting to the use of bearings of special design or dimensions.

Fourth: Resorting to the actual application of anti-friction bearings on typical steel mill equipment and observing their operation over a period of time, so as to satisfy our judgment that the type of bearing used, design of housing and maintenance are correct.

Fifth: Handling each proposal for changeover or new installations, in strict accordance with the service to which that machine shall be subjected.

In conclusion, it can be pointed out that the successful operation of our bearings on several hundred steam railway car journals, of one of the leading railroads in this country, has been accomplished only by the following out of a "slow but sure" policy. Development work in the steel industry is being conducted along similar lines; it is for that reason that we have elected to refrain from discussing details, covering the operation of installations that have now been running over a limited period of time, until we are thoroughly satisfied that the problem is one that can be considered as generally successful.

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*Developments In Electric Heat**

BY A. I. & S. E. E. ELECTRIC HEAT COMMITTEE

GEORGE H. SCHAEFFER, Chairman†

IT is the intention of the committee to present to the membership a report covering the field of electric-heat for the period that has elapsed since the 1926 convention at Chicago. The historical features have been presented by former committees and anything further along this line would be useless repetition. Inasmuch as each particular heating installation is a problem complete in itself—due to plant and power conditions—the subject has been treated in a somewhat general manner.

The most important phase of electric heating to the "Steel Mill Man" to date is Melting—and the various phases of this is given first consideration; then follows "High Temperature Furnace"—and next the "Low Temperature Furnace." It was thought

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expedient to consider to some extent, Miscellaneous Applications and Future Developments. The opinions expressed are not those of any one person, but are the composite opinions obtained by round table conference of the committee.

ELECTRIC MELTING

One of the fundamental principles of electric melting is speed—or time. In order to increase the speed or reduce the time of making a heat it has been found very advantageous to make use of three or more voltages—applied by using its particular switch on the operating panel. After cold charging —according to nature of the scrap—a hole is formed for each electrode with low or intermediate voltage —for about five minutes to smother the arc and save the refractories—the high voltage is then applied and kept on until the burden is semi-molten or the arc no longer protected by the unmelted scrap. The intermediate voltage completes the melt after which low voltage is used for the remainder of the heat.

The proper economic power input for a certain charge is still more or less of an open question. It is influenced by the cost of power balanced against production.

The most economical melting voltage for any particular job depends on the design of the furnace, that is the diameter of shell and height from bath to roof and class of scrap. In a given furnace a higher voltage may be used with success on small light scrap than can be used on heavy melting scrap such as crop ends, etc. For plants where the power demands are taken only on the day load, it is sometimes advisable to use night melting down voltage somewhat higher than the day melting down voltage and thus take advantage of off peak load.

Rapid Charging

As regards rapid charging—in the early days of alloy electric steel furnaces when 6 to 8 and even as long as 12 hours were required for a heat, the 45 minute to 1 hour 15 minutes required from power off to power on, did not amount to a serious delay.

With the application of higher melting voltages and higher power input heats are being turned out in 3 or 4 hours power on to power off. With this shorter cycle the charging time becomes an appreciable part of the total tap to tap time. On furnaces of 15 tons capacity or greater charging cold metal—regular floor type charging machines have been successfully used.

A crane type charging machine is being successfully used for 6 ton furnaces. Actual time required for getting the scrap into the furnaces with the crane type charger is approximately 15 minutes. Various schemes using chutes to slide the scrap into the furnace have been tried with partial success.

The newest arrangement for rapid charging in the ingot steel industry is the removable roof. This type of furnace has been used for a number of years on furnaces operating in steel foundries. It has now been re-designed and at least one application made to the basic alloy steel industry within the past year and it is apparently successful. It should be noted that there are several schemes for removing the roof.

A—Horizontally with roof lifting crane.

B—Attach roof mechanism to the mast and tilt the whole arrangement, including the electrodes, upward through an angle sufficient to clear top of furnace.

C—Pivoting roof and mast structure and swinging around to clear top of furnace.

Recent Installations

During the year the following melting furnaces were installed:

1—¼ ton furnace.
5—½ ton furnaces.
1—¾ ton furnace.
4—1 ton furnaces.
4—1½ ton furnaces.
1—2 ton furnace.
6—3 ton furnaces.
1—7 ton furnace.
1—10 ton furnace.
3—25 ton furnaces.

Total number 27 furnaces.

Total rated tonnage 125½.

Proper Voltage for Foundry Work

During the past 7 or 8 years practically all furnaces put in for manufacture of steel castings have been equipped for dual voltage operation—i. e. taps are arranged on the high tension winding of the transformers for a high melting and a low holding or refining voltage or the high tension winding is switched from delta to Y connection for the low voltage.

Although equipments are installed for dual voltage, in the majority of foundries, operating with satisfactory acid practice, only one voltage is used. The experienced operator, using selected scrap, brings his heat down to the proper analysis and condition when the proper is reached and the heat is poured.

The distinction between basic ingot steel practice and acid casting should be noted. In the former, due to more expensive refractories and long refining periods, 2, 3, and even 4 voltages are used. In the latter where less expensive refractories and little or no refining time is required a single high voltage is used.

Operating Data consisting of such items as power consumption per ton of steel, cost of refractories, electrode consumption, voltage used, etc., is likely to be misleading unless accompanied by complete description of the process and conditions existing in the complete operation.

It is the intention of this committee to have quarterly meetings to review the activity and development and the application of electric heat. It is hoped that these round table discussions will result in greatly facilitating the work of the committee and enable them to render a progressive annual report.

HIGH TEMPERATURE FURNACES

Metallic Resistor Type

One of the most important applications of the high temperature electrically heated furnace of the metallic resistor type made during the past two years has been to the annealing of high grade carbon alloy and high speed steel bars. Within the past two years some 15 furnaces of varying capacities have been installed for this service. These

furnaces are usually of the car bottom type and depending upon the type of steel, the bars may be loaded directly on the car for open annealing, or may be packed in boxes or tubes. Tool steel annealed under proper conditions in electric furnaces of this type has been practically free from scale and decarbonization.

The annealing cycle for this steel is usually long, ranging from 42 to 72 hours, depending upon the size of the charge and the physical requirements of the steel.

A typical furnace of this type has chamber dimensions approximately as follows 4′8″ wide x 16′ long x 2′6″ high. The connected load is 210 KW. An average of 3 ten ton heats per week is annealed in this furnace. The annealing cycle is as follows: Cold charge of 10 tons placed in the furnace with the furnace walls and car at approximately 600° F. Eight to ten hours with full power on are required to bring the temperature of the furnace chamber to 1430° F. An additional 3 to 4 hours are required to soak the charge through. During this period the furnace is controlling the temperature by cutting off and on the full power input of 210 KW. When the charge is soaked through the connection of the heating units in the furnace are changed so that the power input is reduced 1/3 of the normal or 70 KW. for soaking. This requires an addition of 6 to 10 hours depending on the type of steel, thus making the total heating up cycle from 18 to 22 hours. The switch is then opened and the charge allowed to cool in the furnace. Approximately 24 hours are required to cool the charge down to the point where it may be removed from the furnace. Fresh charge is ready for placing on the furnace car as soon as the finished charge is removed and the cycle repeated.

A cycle such as the above allows the use of off-peak power during the night period to a good advantage as the heavy drag on the heating up comes within the usual night period. After the initial absorption has been taken care of the power is reduced to 1/3 the normal for soaking the steel over the day period.

A battery of furnaces may be scheduled to operate in sequence and very economical use be made of the demand—for instance a battery of three furnaces may operate on the equivalent of 1 1/3 times the demand of one furnace.

The main advantage found in the annealing of tool steel has been uniformity of the resulting steel form end to end of every bar. In the tool steel industry the purchaser's specifications are based on very close limits of Brinnell. In cases where business has been let on competitive tests as to uniformity, the product annealed in the electric furnace has stood out as superior to material annealed in fuel-fired furnaces. The chief recommendation for electric furnaces for this industry is found in the number that have been placed in successful operation within the past two years.

Roll Treating

The exceptionally heavy duty being required of steel rolling mills has drawn serious attention to heat treated alloy rolls. This is particularly true in connection with four high sheet mills. The first electrically heated roll treating furnace was noted about three years ago. Eighteen months ago two additional roll treating furnaces were installed. Both these installations were made in steel plants.

A large roll manufacturer is now installing a battery of three furnaces for this purpose. The proper heat treatment of alloy rolls requires very careful heating up and close temperature control such as can be obtained in the electric furnace.

The pit type furnace with split covers is best suited for roll treating. These furnaces are improved models of the gun treating furnaces used during the war, which were the original large industrial heat treating furnaces of the electric type using metallic heating units.

Continuous Enameling

There has been a considerable demand for and a great deal of engineering work during the past 18 months on continuous enameling furnaces for burning vitreous enameling ware, such as kitchen ware, factory lighting, fixtures, stove parts, refrigerator parts, etc. There are now in operation two or three electric furnaces doing this class of work. All of these furnaces so far developed utilize the principle of an overhead conveyor located outside of the furnace with carrying bars extending through a slot in the top of the furnace supporting the work. All of the furnaces developed have been of either the rotary or the straight line tunnel type and are in quite successful operation. At the present time a number of negotiations are being handled for similar furnaces and we predict that this type will supersede all other furnaces if there is sufficient production to justify the installation. So far this type of equipment has not been applied to bath room ware.

Variation In Size And Power

Standard melting furnaces cover a wide range of sizes from 100 pound capacity to 25 tons for cold melting and up to 40 tons for duplexing hot metal. The range In power input on these furnaces is from 50 KVA. on the smallest unit to 7500 KVA. on the 25 ton cold melting furnaces. Designs are carefully worked out on 50 and 60 ton furnaces and with the increased call for quantity production of high grade alloy steels we should expect furnaces of this size to be installed in the reasonably near future.

Heat treating furnaces range in size from small box units, using a few kilowatts for tool treating to units having a connected load of 3000 KW. and in dimensions of 30′ wide x 50′ long.

Pit type furnaces are now in operation having a depth of 40′. Prior to the disarmament conference the United States Navy had contracted for a gun furnace 10′ in diameter x 105′ deep, and part of the material had been placed on the ground. Due to the abandonment of the Navy program the furnace was not completed.

LOW TEMPERATURE FURNACES

Air Drawing, Tempering and Coloring

For certain classes of steel products better working conditions can be obtained and better product insured if the material is drawn, tempered and colored in an air bath rather than in salt, oil, water or lead. In order to do this the oven or furnace must have as nearly uniform temperature throughout the entire working chamber as is possible. This has been approached but never very successfully done until this past year when two or three manufacturers

brought out equipment especially designed to do this class of work. Various schemes are employed but most of them use a careful distribution of heating elements combined with careful air circulation to get uniform heat distribution and these units are being used quite successfully in a number of industries.

Material Handling

The electric furnace is essentially a machine. All the fuel and combustion difficulties are placed back in the power house where the power is generated. The furnace temperature can be automatically controlled and the heating units so distributed that various temperature zones independent of each other, may be created.

All these features immediately lead to the use of electric furnaces for continuous production. These installations have eliminated high priced labor in furnace operation as the electric furnace is fool proof.

Recent developments have been toward the automatic charging and discharging of materials into and out of furnaces. This permits large furnaces to handle big production with a minimum of labor one crew to take care of several furnaces.

The rotary hearth furnace is particularly adapted to automatic discharging and several such equipments have been sold during the past year. The rotating hearth consists of hinged sections or trays. The material is charged manually. When the heated charge has arrived at the discharge point a mechanical device raises the tray vertically and the material is discharged from the furnace. One operator can easily handle two or more furnaces.

A very interesting automatic charging and discharging equipment consists of two 650 KW. rotary hearth furnaces and two conveyor type quenching tanks. Six cylinder crank shafts are hardened and drawn automatically. The only labor required is to place the crank in the hardening furnace charging trough and to take the crank away from the draw conveyor. The complete movement is controlled by a repeating process time clock.

One complete cycle consists of the following operation:

The cold crank is placed manually in the charging trough of the hardening furnace. The clock makes contact and the charging door raises. When the charging door is at the proper height, the charging ram moves forward pushing the crank into the furnace and returns to its rest position. The charging door closes. The hearth moves forward one station, spotting a crank at the discharge position. The discharging door raises; the discharging ram pushes the heated crank out of the furnace and returns to its rest position. The discharge door closes. The hot crank, when pushed out of the furnace is deposited on a counterweighted tray. The weight of the crank overbalances the tray and tray and crank are lowered into the quenching tank conveyor and returns to its rest position. The quenching tank conveyor carries the crank through and up out of the quenching medium and drops it in the draw furnace charging trough. As soon as the crank is placed in the charging trough, the charging door of the draw furnace opens and the movement of the crank through the draw furnace follows automatiically as in the hardening furnace. The crank finally being removed manually from the draw furnace conveyor.

The doors, charging and discharging rams and hearth are motor operated and all are electrically interlocked, making it impossible for a movement to take place until the previous movement is completed. The time clock is adjustable so that various time cycles can be obtained. Six throw cranks with weights varying from 87 to 125 pounds are handled by the equipment. The whole equipment is operated by two men. The equipment has been in service for over a year and operates 24 hours per day. With normal operation, the equipment has a production of 74 cranks, 87 pounds each, or 6438 pounds per hour. The economy is 190 KWH. per ton hardening and 105 KWH. per ton drawing.

MISCELLANEOUS APPLICATIONS

In every manufacturing plant are dozens of heating applications, which can be done more or less economically or more satisfactorily with electricity than with other forms of fuel. These fall under the general class of lead and babbitt pots, drying, baking and japanning ovens, glue pots, air heating, hot table heating and heating of certain parts of machinery with small unit type heaters, which cannot be accomplished satisfactorily in any other way. To cover all of these applications the electrical manufacturers have developed a very extensive and reliable line of heating elements known as space heaters, cartridge type heaters, glue pot, babbitt pots, etc., and these are being applied in considerable numbers.

Roll Heaters

There are now 164 roll heaters operating in the sheet and tin mills of 19 plants. Results in these plants show that use of electric roll heaters has increased first turn production about one-third and decreased scrap loss by 10 per cent.

The increase in production is due to the fact that rolling can be started, on orders of any gauge or width, within the capacity of the mill, pracically from the first sheet bar fed to the rolls. This eliminates the necessity of warming-up iron. As a result the production on first turn approaches mid-week values and the scrap loss and production of seconds is reduced to normal turn rates.

Electric preheating of rolls enjoys the same general advantages that are associated with other electric heat applications, namely, precision of results and general controllability. Electric roll heaters afford a definite performance which is repeated each time they are used. It is therefore feasible to charge a furnace with assurance that the rolls will be in shape to produce the orders charged.

In the electric roll heater the heat is introduced by conduction. The heating elements in contact with the roll surface are but a few degrees warmer than the roll material. The surface of the roll is not subjected to intense temperatures which cause a rapid skin-deep expansion considered by many operators to be very undesirable.

The cost of operation of electric roll heaters is low. It is unnecessary to turn the mills over during the heating process so no power is required for this purpose. The power output to an electrical roll heater is but little more than the power required to

turn over the rolls at normal speed with no metal in the rolls.

As the bulk of the preheating is done on the week-end when the mills are down, it is off-peak power. As such, if power is purchased, it causes no demand charge, only the energy charge corresponding to the lowest block of energy used. Hence it is relatively cheap power. In some instances, where power is generated, it can be developed from blast furnace gas which would otherwise be wasted during the week-end period of low pressure demand.

Inasmuch as the mills are not turning, no lubrication is required, hence no attendance is necessary during the electric preheating process. The labor of two men and a crane is required for placing the heaters on the rolls and for removing them after the rolls are heated. The heaters are placed on the Millwrights after making the week-end changes, requiring but a few minutes. After the rolls are heated it is common practice to clear a 16 stand mill of heaters in 30 minutes.

The electric roll heater is now being used extensively for preheating rolls standing in racks during the week so that roll changes may be made at any desired time to accommodate order changes or when rolls become worn, marked or broken.

A new development this year which has created considerable interest has been the development of heating units encased in standard steel pipes to be placed under the moving parts of railway switches. These heaters are turned on when there is snow or ice and keeps all moving parts free to respond to the action of the motor. These are being applied in quite large numbers to some of our railroads and interurban terminal yards.

In addition to the foregoing, there are many applications for electric heat in the steel industry which today are common practice—such as heating local places—as watchmen's shanties, crane cabs, isolate offices and the like. The main saving here is due to the fact that all elimination of waste and loss, such as condensation on steam pipes running any length, it is quite evident that electric heat has advantages.

Hardening High Speed Steel

Metallic resistors of nickel cromium are practically ideal units for all temperatures up to 1850° F. The economical heat treatment of large production quantities of carbon and alloy steels comes within this maximum temperature. Small heat treating furnaces using nickel chromium units are giving satisfaction for temperatures up to 2000° F. In these furnaces three units are made readily removable.

The hardening temperature of high speed steel is in the neighborhood of 2200° F. which is above the economical limit of the present metallic resistor. A large amount of work has been done toward the development of a satisfactory non-metallic element to cover this temperature range. One furnace using a heating unit of carbon plates and another using a special carbide rod have received considerable attention and installations of both types are in operation. Terminal difficulties and heating unit replacements have restricted the general use of these furnaces.

It is to be hoped that further research and experience will develop a more successful heating unit to operate at temperatures above 2000° F.

Forging

Forging heats require still higher temperatures. While drop forging steels are worked at 2150° to 2200° F. the furnace temperatures must be higher—up to 2500° to 2600° F. in order to get quick heating.

An enormous field awaits the development of an economical unit to work at these temperatures.

Heat Treatment of Rails

There has been considerable engineering discussion for several years on the subject of heat treatment of rails, but practically no work has been done in this country along this line. However this idea is being taken up actively in Europe and a number of experimental installations of heat treated rails have been made. It is still too early to get any data as to whether or not this process is justified. We also know that one of the large Steel Companies in U. S. has supplied two or three relatively small orders of heat treated rails and that they are being placed in service in this country. From interest evidenced by the various Steel Rail Makers, it is likely that within a few years this will be more or less standard work, at least, for certain classes of service.

Combined Use of Electricity With Other Fuel

A development which has taken place within the last 18 months has been the use of both electric heating elements and some other form of heating medium in the same furnace. Several furnaces have been placed in operation using oil for the bulk of the heating, with heating elements on the side walls with automatic control to regulate the temperature. These are proving apparently quite satisfactory and for certain applications should be all right. Another application has been the bulk annealing of brass tubes where cars containing the tubes are heated in large boxes on cars without regards to the heat distribution in large gas fired ovens. When they have reached approximately ¾ of the temperature desired, the cars are transferred to electric furnaces where the distribution is exactly right and the temperature is controlled automatically and heating is continued at a slower rate in this furnace. This application is working out quite economically and apparently is satisfactory.

Hardening in Cyanide

The hardening of gears in Cyanide has been a source of worry to the automotive industry. For certain classes of work this hardening process gives the best wearing qualities. On the other hand, it is an expensive operation and does not lend itself to straight line production so essential to mass production. Cyanide pots inherently must be small which results in large floor space and low production per operator for the process. The time required to heat in a cyanide pot varies from 12 to 20 minutes.

Recent experiments have shown that if the piece can be heated in a furnace to the temperature of the cyanide pot and then immersed in the cyanide pot, it would only require a minute or less to give it the Cyanide treatment. These experiments have developed the fact that the pieces must be preheated in an electric furnace. When preheated in a fuel fired furnace, the scale formed on the surface will not permit the cyanide to readily penetrate the surface, resulting in difficulty in obtaining a uni-

form product. With the electric furnace, the scale is slight and does not cling to the surface like the fuel furnace scale.

A recent installation consists of four electric rotary hearth furnaces, two electric alloy heated Cyanide pots and four conveyor quench tanks, which gives two complete equipments. The materials are preheated in the rotary hearth furnace, then dipped in the cyanide for one minute or less. They are then dropped into the first conveyor quench tank and delivered to the rotary hearth furnaces. After the draw, they are dropped into the second conveyor tank in which the quenching medium is kept at a constant temperature by immersion electric heating units. Transmission gears treated in this manner have shown a life of eight to ten times the life of the same gears treated by the old Cyanide method and practically no back lash has developed during their useful life.

Bright Annealing

The subject of bright annealing of steel strips and sheets has been discussed for a number of years and has been done in a number of places more or less successfully with box type or batch type furnaces by using inert or reducing atmosphere in the furnace. There is a demand in this country for a continuous furnace which will do bright annealing and several experimental installations have been made. The information regarding these installations is very meager and it is very unreliable. Apparently difficulties are still being encountered and these are not entirely successful. There is no question but that we will continue to work along this line until this process is worked out satisfactroily.

Electric Heating of Hot Tops of Steel Ingots

This operation was ably presented before the Pittsburgh Section on December 12, 1925 and received with great interest by our membership. The author Mr. F. C. Watson, a member of "The Electric Heat Committee" is authority for stating that there has been a gradual increase in percentage of good ingot heads—due to higher proficiency in the handling of the operator.

This applies, of course, to nickel and monel ingots. It has not been tried successfully as far as we know to steel and alloy ingots. The Committee feels as though this scheme has worth while possibilities for the steel and alloy ingot producers.

HIGH FREQUENCY FURNACE DEVELOPMENTS

The past year has shown considerable progress in the field of high frequency melting. Approximately 12000 tons of copper nickel have been melted by one company with a power consumption of approximately 430 KWH. per ton. During this period one silver melting furnace has been installed having a capacity of 1000 pounds. This furnace has been pouring between 1 and 4½ tons of silver per day with a power consumption of 11 pounds per KWH. or 182 KWH. per ton. A 450 pound steel melting furnace has been installed by a large manufacturer of seamless steel tubing and is being used for the production of special steel castings of precise analysis. Power consumption on this furnace is approximately 650 Kw. Hrs. per ton measured on the line side of the motor generator set. This is very good economy when the size of the furnace is considered and reflects credit to the furnace designers when it is considered that the furnace is charged with the power losses in the motor generator set.

Another high frequency induction furnace and frequency changer has been installed and in melting various metals has shown the following economics:

Nichrome	690 Kw. hrs. per ton.
Armco Iron	840 Kw. hrs. per ton.
Mild Steel	625 Kw. hrs. per ton.
Nickel Steel	600 Kw. hrs. per ton.

The above values were obtained on heats of approximately 350 pounds and are in terms of low frequency power consumed.

In addition to the furnaces installed in this country during the past year there is at present under construction a 600 pound furnace and electrical equipment for export to Sweden. During the past year high frequency power has been consistently meeting the expectations outlined in the report of this committee for last year.

Tests have been made on conductive heating with high frequency ¼-inch steel rod has been heated from cold to cherry red while moving at the rate of 60 feet per minute, with a power consumption of 110 KW. ⅜-inch rod has been heated to the same temperature at the rate of 25 feet per minute, with a power consumption of 160 KW.

The high frequency field has called for the development of special capacitor units, and there has been developed a special unit rated 93 kv-a. 900 volts 2000 cycles. This unit is mounted in a case of the same dimensions in which a unit of 5 kv-a. 2300 volts 60 cycles is mounted.

It was only by the hearty co-operation of the entire committee that this report materialized. Thanks is due to every one of its members for his effort. For myself, on account of the good fellowship and hearty co-operation, the work has been a great pleasure and in addition highly instructive.

It is one wish that those present will add to this report by freely discussing anything they find of interest.

Safety Division Reception and Luncheon

Informal reception for members and guests under the auspices of the Safety Engineering Division of the A. I. & S. E. E. This affair will be held at the Pittsburgh Athletic Association Annex (Old University Club) at 12:30 P. M.

*Safe Practices In Connection With The Operation of High Tension Power**

By T. E. HUGHES†

THE problem of protecting electrical workers of the steel industry from hazards in the installation and maintenance of high tension equipment is becoming more important each year.

The public utilities have made marked progress in developing operating methods whose primary purpose is the prevention of accidents, and in view of the progress that they have made, it would seem that the easiest way for the steel industry to protect their men would be to adopt what had been found most effective in the other field. However, the conditions existing in the power systems of the steel industry differ somewhat from the public utilities and it seems desirable to outline steel mill conditions at this time, and if possible determine what changes should be made in public utility safety practice to make it applicable to the steel industry.

The principal difference between the high tension systems of the steel industry and those of the public utilities are as follows:

(1) The physical extent of the steel mill system is small as compared to that of the central stations.

(2) Important load centers in steel mills usually are supplied with power over two or more separate routes. Central stations frequently have revenue load connected to lines between distribution centers. Hence, steel mills can do all maintenance work with de-energized lines, while central stations work with some circuits alive.

(3) Public utilities employ system operators. Steel mills do not, as their systems are smaller and necessity of system operators has not been apparent.

(4) The system of charts and reports used by the central station industry is not essential in the steel industry because the number of gangs working on the lines is generally very few.

(5) Steel mills use lower operating voltages than central stations.

A short time ago an analysis was made of the principal contributing causes of electrical industrial accidents and it was found that some phase of man failure predominated in nearly every instance. In order to emphasize the conditions which exist, and which must be overcome among the men who are doing this dangerous class of work, it is desirable to review these causes and afterwards endeavor to offer means of abrogating them. The seven basic causes are as follows:

(1) Ignorance.
(2) Haste.
(3) Dependance on others.
(4) Thoughtlessness.
(5) Lack of discipline.
(6) Defects in physical condition.
(7) Inadequate illumination.

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†Gen. Foreman, Duquesne Works, Carnegie Steel Company, Duquesne, Pa.

The importance of these various causes of accidents is sufficient to justify detailed discussion and presenting a few accident examples which will illustrate the various causes.

(1) Ignorance: Men are assigned tasks without being given proper instructions as to the safe performance of their work, or an investigation of their ability to complete the task in accordance with the instructions. The following incident offers an example:

Figure 1 is a diagram of a power house and substation formerly existing in a local steel mill. The reader will not that reverse current relays could not be used on either of the D.C. Circuits shown, as they serve as tie lines and feeders as well. The generator in substation B was equipped with reverse current relays, but for some reason they did not function. The cause for clearing up lines in this particular case was to clear the entrance structure at the power house for painting. Operator at Power House A instructed operator at Substation B to maintain his D.C. connections from D.C. steam station C through tie line and third rail so that he could maintain D.C. voltage; also to disconnect his machines, trip high tension running

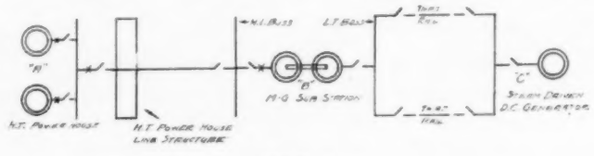

FIG. 1.

switches and pull high tension line disconnects. For some unknown reason he failed to clear up one machine. Operator at Power House A called on phone to station B wanting to know if this station had been cleared from the line. Operator at Station B answered yes! Operator at Power House A cleared his line by tripping oil circuit breaker, pulling line disconnects and shut down the entire station. It appeared the men in charge of clearing lines, owing to the fact that all generators were shut down and switches out, decided that a short circuiting and grounding chain was not needed. At least, they did not provide one. Due to the carelessness of Operator at Substation B, the machine motored due to the connection of D.C. generator to the tie line and third rail. This action converted the high tension motor into a high tension generator, and fed back a high voltage current to the structure at the high tension power house.

The painter was instructed to proceed with his work, and as soon as he came in contact with the lines on the structure, he was electrocuted.

(2) Haste: Electrical workers as a class tend to do everything possible to complete work in the minimum possible time. Perhaps this is due to the fact that electrical maintenance jobs usually mean power interruptions, and interference with industrial production.

Figure 2 illustrates line arrangements in case of near accident caused by haste.

Trouble developed during the night turn on the West River Circuit between main power house and No. 4 Substation, which are about one mile apart. This circuit is parallel and directly under the West HZ Tie line, which was carrying power to the other steel works. The night turn foreman located the trouble about midway between the two stations. The lower outside phase had burned off and was hanging near the pole. Both Power House and Substation operators were instructed to clear the line, by tripping oil breakers and opening line disconnects and to leave the West HZ Circuit, immediately above the line in trouble, hot. The night foreman climbed the pole next to the parted line and tested out the circuit with a small chain attached to the wood pile. After short circuiting all three lines of the circuit, he assumed the line was clear and safe to work on. To be sure conditions were safe, the foreman decided to apply a more rugged short circuit which was accomplished by pulling a steel chain over the wires with a small rope from the ground. As the chain touched the lines it at once burned loose from the rope. Of course, this presented quite a mystery and incidentally a very good lesson. At some time previous to the trouble, the sag in the lines of the circuit above had been increased, allowing the upper line to come in contact with the top-wire of the lower circuit. If men had worked on the line without taking time to pull through the second chain, a fatality might have resulted.

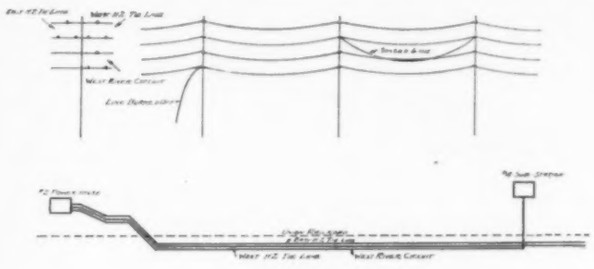

FIG. 2.

(3) Dependence on Others: All industrial workers are prone to assume that fellow workmen will perform their function in the chain of operations which assures complete safety protection. And as a result, many are lax in checking safety precautions, unless they are continually urged to do so by their foreman.

Figure 3 illustrates a condition of this nature.

Trouble developed on No. 4 Feeder reactor at power house which required the removal of a reactor from its cell. Switchboard operator had been instructed to clear the circuit by opening the front and back bus oil switches, their disconnects and the line disconnects. He completed his instructions except opening the disconnects on the back bus oil switch. Instead of the workman checking up on all movements of the operator he assumed everything was clear and started to work without providing short circuiting or ground protection. Shortly after he started, the center shoe rod on the oil switch broke and completed a connection from the main bus up through the reactor. Fortunately at the time this contact was made the man was working away from the reactor, and his attention was called to the condition when the hot line flashed on his tools with which they were making contact.

(4) Thoughtlessness: Failure to consider the possible affect of an action either separately or in combination with a series of actions on the part of his fellow workmen.

Figure 4 illustrates an accident which caused considerable damage to equipment, loss in production, and also severe injury to a thoughtless employe.

Substation B and Bar Mills C and D were receiving power over the West Alley and East River Circuits from Power House A, both circuits being tied together at Substation B through disconnecting switches. Trouble developed in the oil circuit breaker of the West Alley Circuit in Power House A which tripped both circuits. Power House operator discovered the trouble and immediately transferred all substation and bar mill load over to the East River Circuit. This also fed back on West Alley Circuit to transformers a. b. c. Shortly after service had been restored, the operator at Power House found that necessary repairs to the damaged breaker could not be completed with power feeding back over West Alley Circuit. He called the operator at Substation B and asked him to clear up the circuit in question, without any consideration of the transformer load. Under this transformer load aggregating 350 K.V.A. the substation man proceeded to open his disconnects. He got one switch open, but the remaining switches, as well as the outdoor Substation busses were badly damaged. The mills were delayed 1½ hours and one of the thoughtless operators severely burned.

(5) Lack of Discipline: Orders are usually disobeyed because the worker feels that he can give a quicker and better service by a short cut method, or because he is not sold on Safety and feels the rules and regulations needless. As a result groups of men frequently take hazards which are unnecessary and contrary to the rules. The only way to cure this tendency is to enforce strict disciplinary measure each time that an instance of such is discovered.

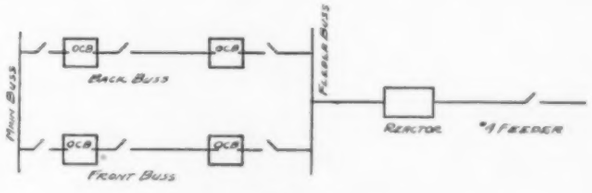

FIG. 3.

Accidents due to the lack of discipline are so prevalent as to make examples superfluous.

(6) Physical Defects: There are three physical defects which cause accidents, namely, poor vision, poor hearing and poor co-ordination. Poor hearing and poor vision are defects which are easily discovered by conscientious medical examination. A man having such defects rarely enters an organization where his employment would be hazardous. However, it frequently happens that after original employment, the men are transferred from one class of work to another without a medical examination and as a result are given work for which they are physically unsuited. Poor co-ordination is a defect which has not been given careful attention by the medical au-

thorities employing electrical workers as its importance justifies. Any defect in the nervous system that handicaps a man in having his hands perform what his brain directs makes him unfitted for electrical work. Unfortunately, the degree of co-ordination is a thing of which we have no direct measure. Until some standard of selection is developed this defect can only be prevented by observation on the part of the foremen.

(7) Inadequate Illumination: The necessity for 24-hour operation in the steel industry requires the electrical maintenance department to make repairs regardless of the time that a failure occurs. It therefore, frequently happens that men are required to make repairs on high tension equipment in the dark. While it is as simple to disconnect lines during darkness as in daylight, the hazards of climbing and working in the air under poor illuminating conditions are so much greater that provision should be made to properly

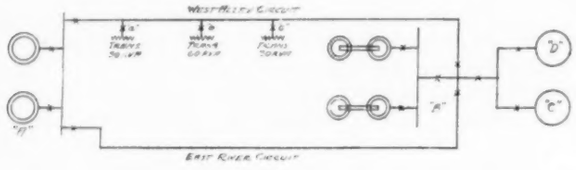

FIG. 4.

illuminate such jobs as they occur. So far little attention has been paid to this side of the industrial electrical safety problems. This hazard can be readily eliminated by equipping switchhouses, substations, etc., with a system of battery fed lighting and providing portable flood lights for field work.

The following are some general rules for safe operation during normal and emergency periods:

1st. The operators at the various plants should be at all times familiar with the relative importance of the various local loads as well as the loads of other plants, if interconnected, so that they can readily make a load reduction to meet any emergency condition. These men must be resourceful, have good judgment and ability to think quickly and accurately. They should at all times have a mental picture of the apparatus which they are to operate, together with its location and relation to the other apparatus. Where groups of plants are interconnected, or the system is unusually extensive all operators should be under the supervision of a system operator who is responsible for the protection of all men working on the system.

2nd. Operators must be informed as to the names of men who are authorized to issue switching orders. In no case should he taken orders from any other source, except in extreme emergency when circuits may be de-energized. Power must never be put on a circuit unless orders are received from a duly authorized person.

3rd. Each power house should have a miniature switchboard showing in detail the arrangement of generating equipment, feeders and the tie line, for use of the operators and their assistants.

After each switching order is completed the connection should be duplicated in detail on the miniature board. A system log should be used in connection with the miniature switchboard; this log should furnish a brief statement classifying each operation in connection with a switching order together with a report of load conditions and of any trouble or repairs required to the station equipment. This log sheet should cover at least 24 hours of operation to serve as a guide to each operator as he comes on duty.

4th. The importance of quick and efficient communication between power plant operators during the normal or emergency operating conditions is so essential as to justify separate telephone system. If the local telephone system is used for dispatching service, switching operations in emergencies are generally retarded by busy telephone lines and as a result the operator is unable to get in touch with the proper persons to restore service. The telephone and miniature switchboard should be located so that the operator has full view of the miniature switchboard, station switchboard and indicating instruments while using the telephone.

5th. When high tension equipment is to be out of service for repairs, the operator should be notified as far in advance as possible, in order to make any load adjustments that may be required. In plants where important tie lines exist, high tension equipment should not be disturbed during peak hours.

6th. Persons other than operators or authorized electrical department workmen should be refused admittance to galleries, switching yards and electrical equipment in general, unless accompanied by authorized employes familiar with all hazards.

7th. All circuits and equipment on the system should be definitely designated by some simple method. The method adopted should be distinctive and have a very definite meaning in order to give all parties concerned with an operation a definite mental picture of just what is affected by each operation.

8th. It is vitally important that workmen consider equipment alive until it is definitely determined that it is disconnected, short circuited and grounded. It is equally important that the methods used insure this condition be as direct and simple as possible. With that end in view it is advocated: First, that only one type of sign or card be used on the switchboard and that it be designated simply with the words, "Men Working on Line;" second, that after all switching operations incident to clearing equipment in preparation for repairs has been complete and the operator reports "All Clear," grounding and short circuiting switches be closed where installed, or chains used to short circuit and ground lines when such switches are not available. If these two simple regulations are followed no accidents will occur.

It may be argued that chains as short circuiting devices are hazardous and unreliable. While they are not considered as satisfactory as the usual short circuiting switch, they can safely be applied by first throwing rope over the conductors and then pulling the chain into place. Possibly, such rope should be treated by boiling in paraffin, kept properly protected from moisture, and then it can be used with absolute safety at 6600 volts. It is hoped tests will prove such rope equally safe on much higher voltages. There is no question that chain made up of 3/16" spiral links will carry sufficient current to operate relays and trip any breakers not previously opened on voltages of 2200 volts and higher. On lower voltages, larger chains may be used and good contacts with lines assured by wrapping the chain around the conductors.

Conclusion

This paper has endeavored to point out some things which appear necessary to eliminate accidents in the operation of steel mill transmission systems. Of these, by far, the most important feature is education. Much can be done to avoid accidents occasioned by Thoughtlessness, Haste, Dependence on Others, by Safety Propaganda in the form of Meetings, Demonstrations, Talks by Foremen, and the Explanation of Accidents, etc. A well-managed system insists on obedience to orders, the more nearly discipline approaches the military standard the fewer the accidents will be. Safety devices can not be substituted for Ignorance, Thoughtlessness or Disobedience to orders, but where good management exists, systems of instructions, short circuiting and grounding devices are effective checks to carelessness and lapse of memory. Instructions and safety devices should be simple, orders few in number as possible, and in the last analysis a simple sign used in connection with short circuiting chain is sufficient to prevent a large majority of potential accidents.

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*Recent Boiler Plant Installation at Edgar Thomson Works, Carnegie Steel Company**

By R. D. ABBISS†

BOILER PLANT

PRODUCTION incessant and ever increasing is the creed of the modern steel plant. A continuous supply of steam and electrical energy unlimited to the extent that output shall not be curtailed is essential to this production. While this continuous reliable service has been, and will continue to be, the first requirement of the steel works' generating units, efficiency is a factor that demands more and more attention. The design of the modern steel work's boiler plant, although it may be comparatively diminutive from the standpoint of the public utility man, is a matter for careful study and individual design in order to obtain the highest economical operating efficiency together with positively continuous and reliable service. Both of these factors were kept to the foreground when adopting the plan of finally replacing the seven boiler plants, containing 168 boiler units located at various points in the plant in near proximity to the steam consuming units with two central power producing plants. The present Stirling Boiler House is the first step towards the completion of this plan.

The building is all steel construction, 328 feet long, 84 feet wide, with ground floor, firing floor and fan floor, together with the necessary intermediate operating platforms. The structural members of the building are arranged so as to act both as the supports and the buckstays of the boiler setting. A general idea of the construction is shown by the accompanying photographs, Figures No. 1 to No. 7, inclusive.

The boilers are B. & W. Stirling, Class No. 13, No. 40, twin-units, arranged in a single row in the center of the building. Each twin unit is 40 tubes wide and consists of 6 steam drums each, 42" diameter, 25'3⅛" long; two mud drums, 48" diameter, 21'9⅜" long, with 1600—3¼" tubes, and contains 22,250 sq. ft. of heating surface. Figures No. 1 and No. 2 show a longitudinal cross-section through the Boiler Plant.

Figures No. 8, No. 9 and No. 10 show a cross-section through settings as arranged for Blast Furnace gas, Boilers No. 1, No. 2, No. 3 and No. 4, for either Blast Furnace Gas or coal Boilers No. 5, No. 6 and No. 7, and for coke breeze, Boiler No. 8, respectively. These cross-sections emphasize the relative positions of the boiler, gas mains, gas burner, stokers, air preheater, air mains and the forced and induced draft fans.

The boilers are set high, the steam drum being 41'1½" above the firing floor. In considering this high type of setting, attention was called to the fact that some difficulties have been encountered in the maintenance of this type of setting at a reasonable cost. This condition is caused:

First, due to the nature of the settings themselves, the brick have to maintain a larger compression load than in the lower type settings, and, therefore, more care has to be exercised in their design.

Second, with the high furnace more complete combustion takes place within the furnace before the gases are cooled by contact with the heating surface of the boiler proper. This complete combustion produces a higher furnace temperature which has caused trouble with some settings.

Third, with the high settings higher rates of combustion have been obtained with correspondingly higher furnace temperatures. After due consideration it was decided to build the setting of first quality fire brick, using non-clinkering furnace block to prevent clinkering and slag adhesion to the walls above the stoker and in the clinker grinder pit. This decision appears to be entirely justified as the settings have proven entirely satisfactory.

Each of the seven boilers arranged for gas firing is equipped with four variable orifice box type pressure burners, two on each side of the boiler. The variable orifice is obtained by means of two wing valves, mechanically connected, which are operated automatically to maintain the proper pressure in the burner box. Figure No. 11 shows a cross-section through the burner proper; Figure No. 12 shows an exterior view, and Figure No. 13 a view of the burner nose from within the boiler after installation.

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*To be Presented at Annual Convention, June 13th to 18th, 1927, Pittsburgh, Pa.

†Special Engineer, Carnegie Steel Co., Braddock, Pa.

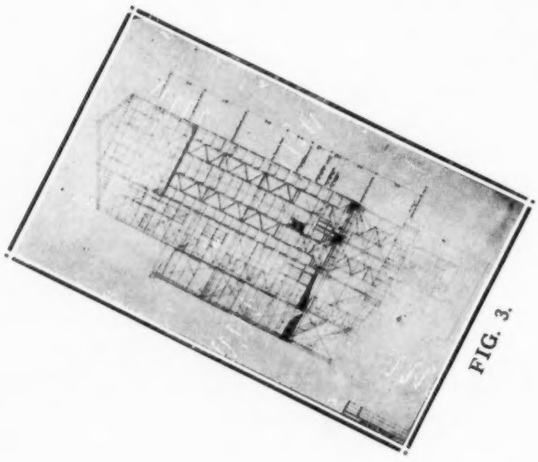


FIG. 3.

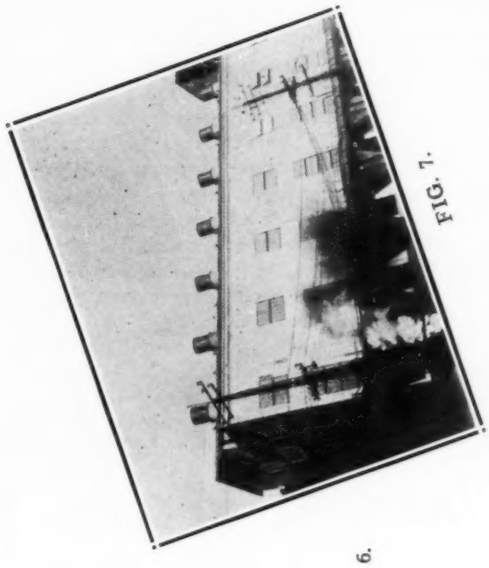
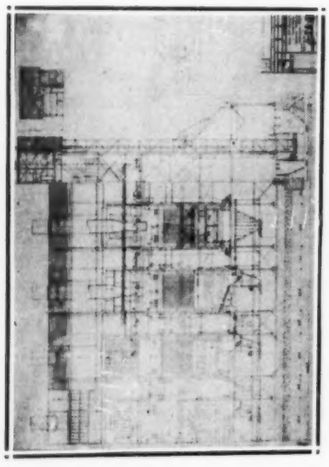


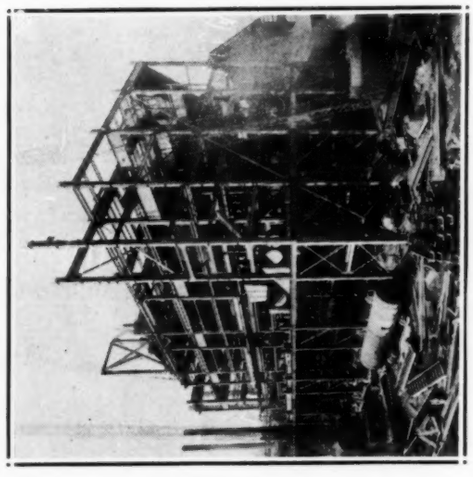
FIG. 7.

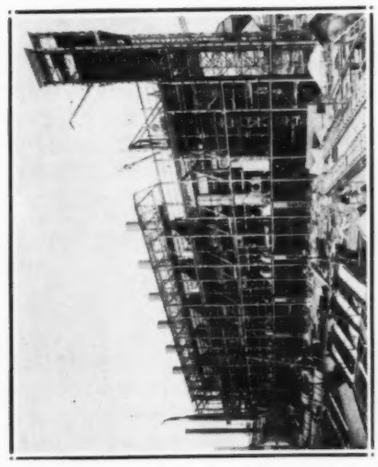
FIG. 2.

FIG. 4.

FIG. 6.







FIGS. 1 TO 7.

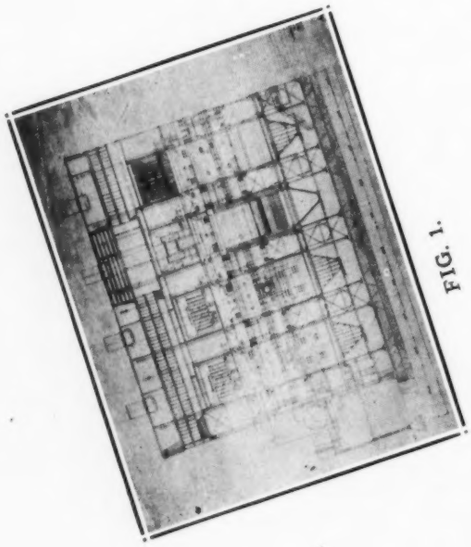


FIG. 1.

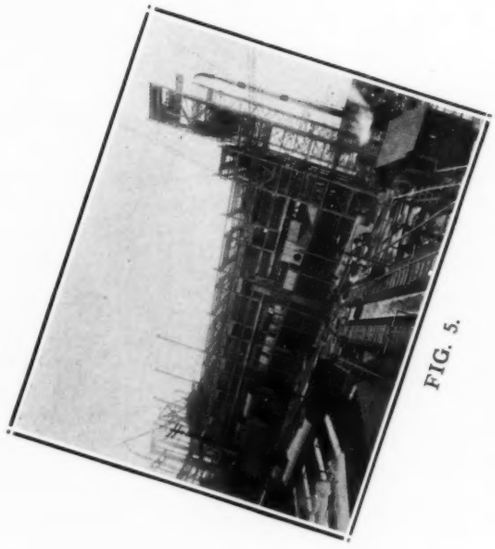


FIG. 5.

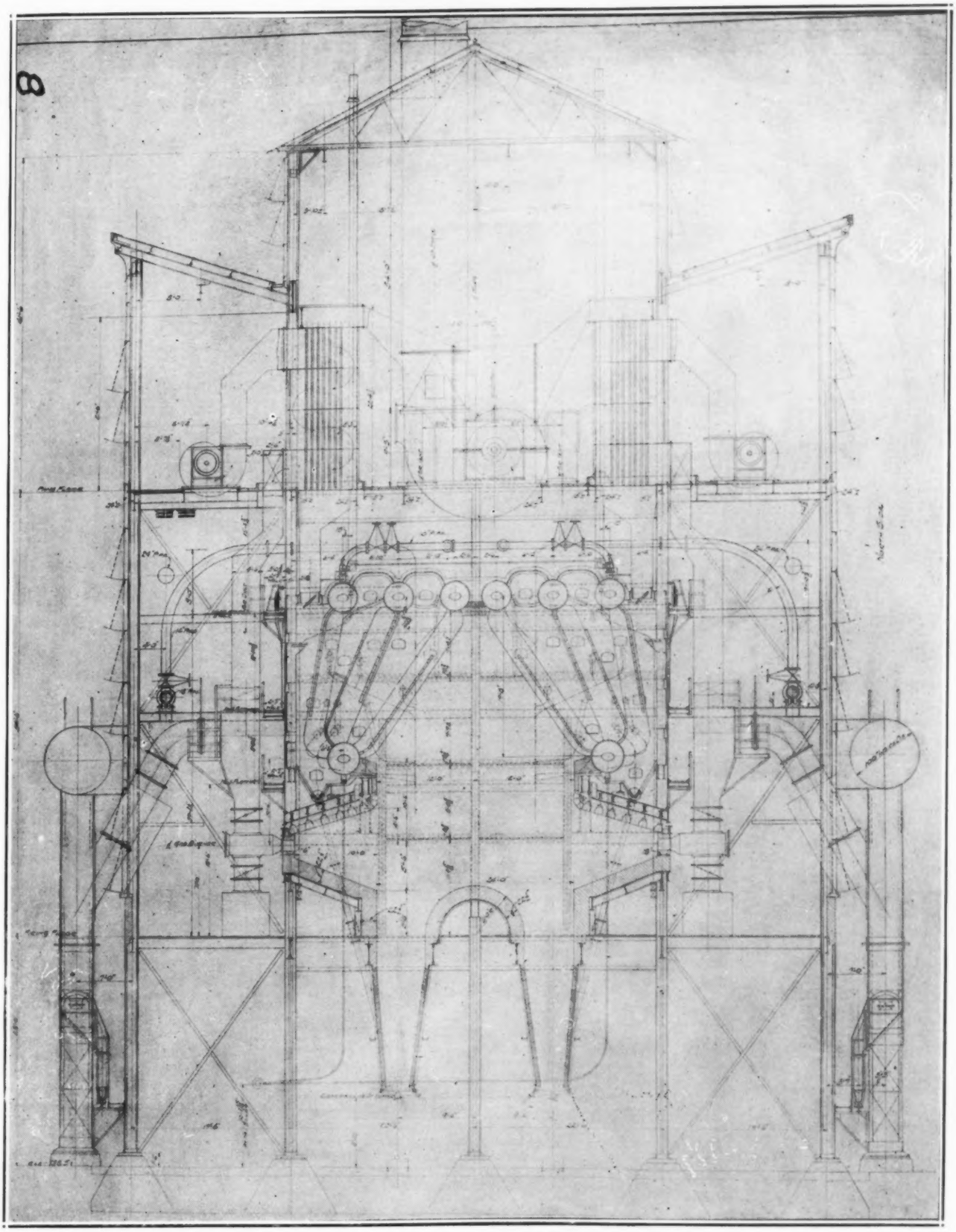


FIG. 8.

FIGS. 1 TO 7.

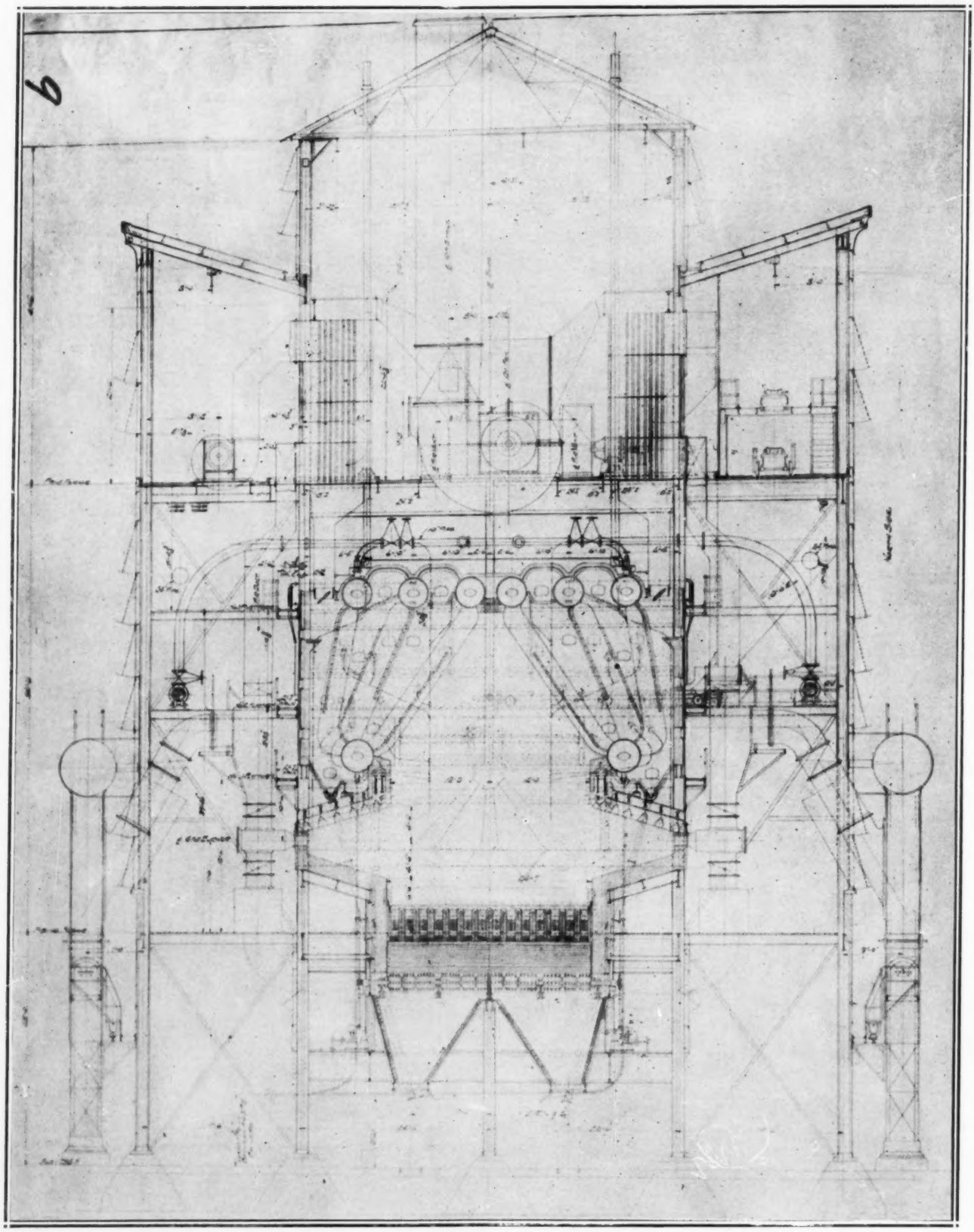


FIG. 9.

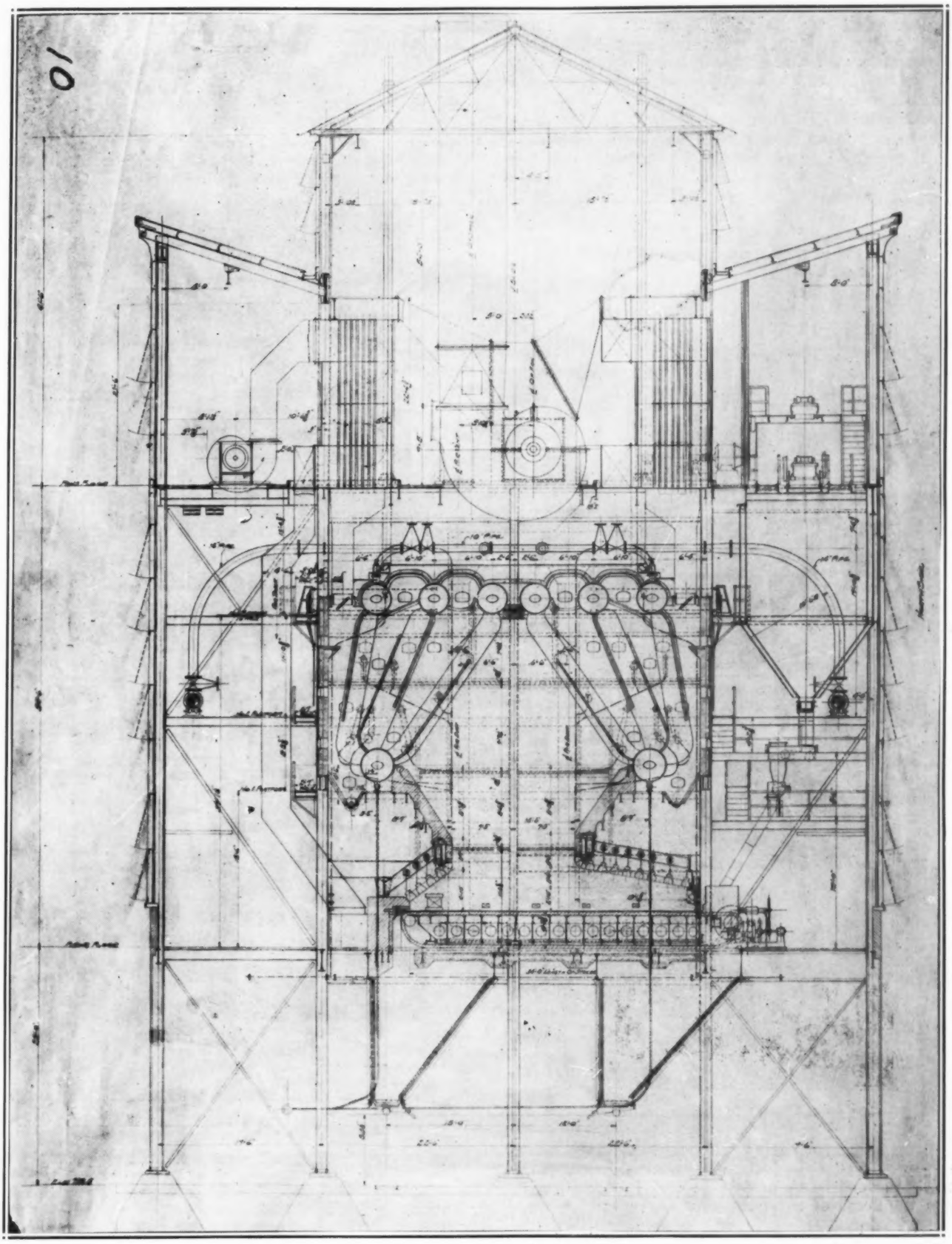


FIG. 10.

These burners are of sufficient size and capacity to handle the gas at a static pressure of 1½" of water, required when operating the boiler at 300% rating. The burners maintain a short snappy flame and are guaranteed to maintain complete combustion; no CO and less than 1% oxygen within eight feet of the burner nose over the entire operating range of from 100 to 300% rating.

Boilers Nos. 5, 6 and 7 are equipped with Combustion Engineering Corpn's Frederick, 14 Retort, type G-36, stokers, 13 tuyeres wide and 30 tuyeres deep. High side, wall tuyeres, are used to prevent

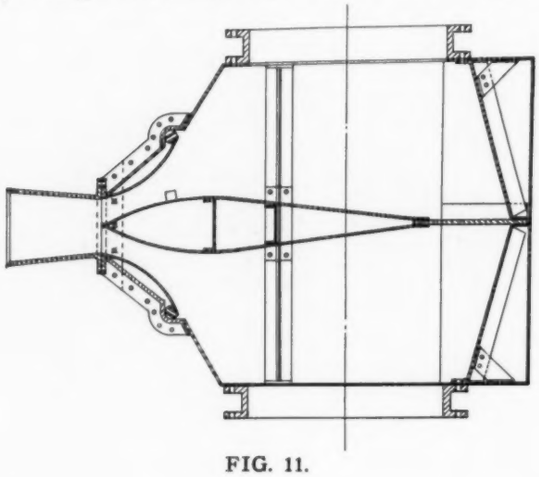


FIG. 11.

the formation of clinker along the side walls of the furnace. The projected area, 423 sq. ft., is divided as follows:

282 sq. ft. in the underfeed section,
57 sq. ft. in the overfeed section,
84 sq. ft. in the clinker grinder section.

Each stoker is divided into five sections, each section being driven by a 5 HP, 335-1350 RPM motor, thus permitting the adjustment of speed of the different sections to suit the fuel bed.

Figures Nos. 14 and 15 show two views of the stoker.

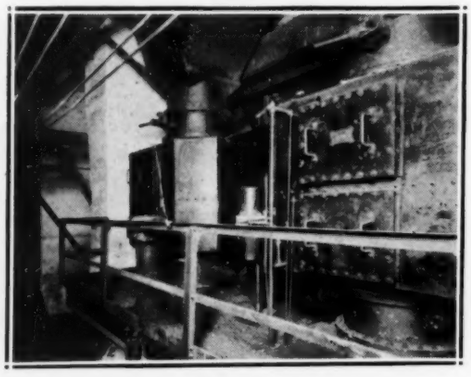


FIG. 12.

The clinker grinder, Figure No. 16, is of the single roll type built in two sections, each section being driven independently by a 5 HP motor which is a duplicate of the ones used on the stoker drive.

No. 8 boiler is equipped with an Illinois Chain Grate, 19'0" wide and 34'0" long, having a projected area of 646 sq. ft. and is used to burn coke breeze.

A feature of this stoker is the down-draft section at the front of the stoker used to aid the starting of combustion with the low grade fuels.

An especially interesting feature of this installation is the fact that all of the boilers are equipped with air preheaters. These preheaters are of the B. & W. tubular type, each heater containing 482—4" tubes and having 9,668 sq. ft. of effective heating surface.

Figures Nos. 17, 18 and 19 show views of the heater during erection.

FIG. 13.

The indications at present are that the results from the preheaters will be more favorable than the theoretical calculations would indicate. Preheated air not only returns a certain number of B. T. U's, but also tends to produce a more rapid combustion, usually accompanied by a shorter flame and a reduction of the excess air required. In addition, the efficiency of heat transfer is improved due to the higher furnace temperature and the greater absorption of radiant heat.

The solid fuels, coal and coke, are received by rail and dumped from the cars into hoppers from which they are automatically fed into the Link-Belt

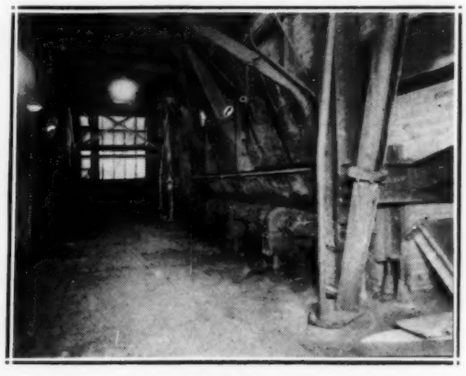


FIG. 14.

skip hoist, views of which are shown in Figures Nos. 20 and 21. The hoist in turn dumps the fuel through a feeder onto a stationary conveyor equipped with magnetic pulley for the removal of foreign material. The fuel is then crushed and placed on the traveling conveyor which supplies the various bins, from which it is delivered by conveyor to the automatic scales

which empty into the stoker hopper. In order to obtain the space necessary for housing the automatic feeders for the skip hoist, it was necessary to sink a caisson, a view of which is shown in Figure No. 22. Allen-Sherman-Hoff ash gates and hoppers are used on all of the boilers; feed water is used to operate these gates. The ashes are dumped from these hoppers into a Lakewood Engineering Co. ash car of 200 cu. ft. capacity. This car is of the side dump type and is equipped with small automatic couplers. An Ellwell-Parker Electric Co. tractor

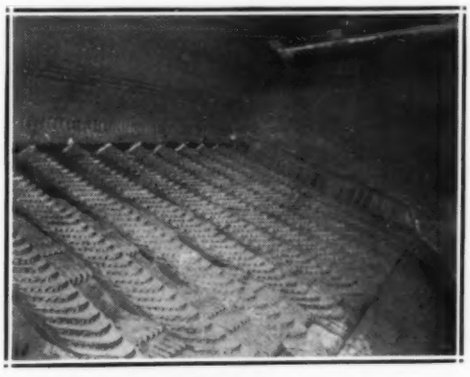


FIG. 15.

equipped with an Edison 8-A-42 cell battery is used to move the ash car. The ashes, which are dumped into the same skip that is used for coal, are deposited in a tank, see Figures Nos. 20 and 21, over the broad gauge tracks from which they are removed as occasion demands. Figure No. 23, a view of the ground floor, shows the track system, ash gates, ash car and tractor.

As the water in our plant is obtained from the Monongahela River, the acidity of which varied in 1926 from 1.23 to 3.23 grains per gallon, it is necessary to introduce lime into the water before supply-

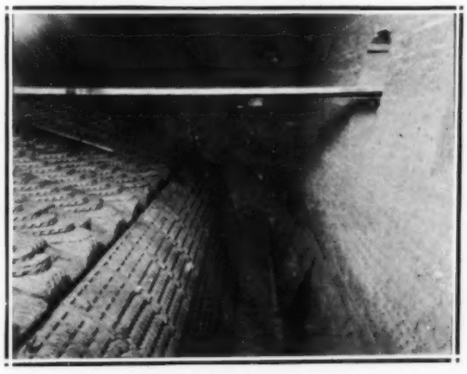


FIG. 16.

ing it to the plant for its various demands. The acidity of the water supplied is kept at 0.5 grains per gallon or under, at all times. A portion of this supply water which has passed through the cooling system of a blast furnace and a barometric condenser, thereby increasing its temperature approximately 67° F., is used for boiler feed supply to the treating tanks. The Treating Plant is of the intermittent type, consisting of 10 tanks of 230,000 gallons capacity each. A resume of the treatment of each tank is as follows:

After introducing the lime charge and thoroughly stirring the tank a sample is taken and treated with a 50th normal sulphuric acid solution to ascertain if all bicarbonates have been changed to carbonates. If the sample does not show that this result has been obtained the tank is re-treated until the desired result is obtained. The soda charge is then added in a similar manner in sufficient quantity to increase the carbonate 16 grains above that of the lime treatment. After settling for

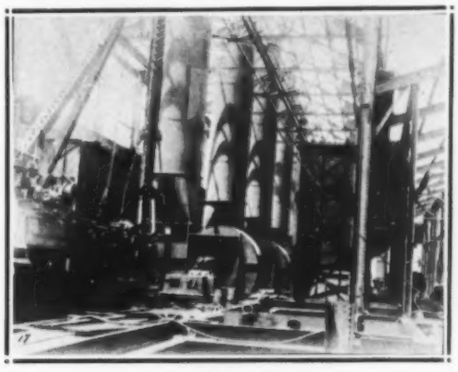


FIG. 17.

about 9 hours, the water is run through a gravity sand filter to the clear well from which it is pumped to the heaters and thence to the boilers. Daily tests are made of the total concentration of the water in the boiler and, we have found that by blowing down every 8 hours we are able to keep the concentration under 300 grains per gallon and the causticity and alkalinity at 60 and 70 grains per gallon, respectively.

The steam piping is supported on pipe rollers and hangers, some of which are provided with springs to take care of the expansion. All piping for both steam and feed water over 4" is extra heavy

FIG. 18.

steel welded wherever possible. All joints are vanstoned. The fittings are cast steel for steam pressure of 250 pounds and total temperature of 650° F. Wherever a weld was used the pipe was threaded and inserted in collar so that the threads were tight and end of pipe butted to adjoining pipe. The ends of the collars were then welded to the pipe. Two Crane Co. separators, Figue No. 24, each having two 18" inlets and one 24" outlet are installed in the steam header to prevent the possibility of water entering the steam. Johns-Manville sponge felt

covering 3" thick is used on all high pressure steam lines.

The most economical use of the Blast Furnace gas, which is our principal fuel, presented a very difficult problem, since the supply of gas bears no definite relation to the steam demand and coal and coke breeze must be used to generate that part of the demand above that supplied by the gas, and to

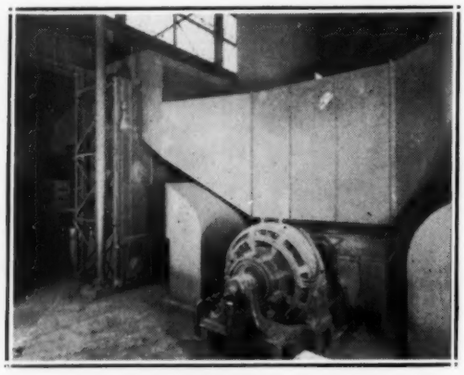


FIG. 19.

tide over during periods of reduced gas supply. To continuously and automatically proportion the air to the quantity of gas available, and maintain a predetermined pressure in the combustion chamber, combustion control and pressure regulating apparatus as manufactured by the Benjamin Engineering Co. was installed. This control, which is adapted to

FIG. 20.

the requirements of the Gas Combustion Co's. burners, is electrically operated from the 250 V. DC mill feeders. The requirements of this control are:

1. The maintenance of from 0 to minus 1/10th inch of negative water pressure in the combustion chamber:
2. A constant pressure of the forced draft at the burners;
3. The regulation of the burner wing valves to maintain a constant pressure of the gas pressure in the burner box.

There are no connections between the apparatus on opposite sides of the unit, the burners and forced draft fans on the one side being operated entirely independent of those on the other side.

The pressure of the combustion chamber is controlled by a pressure regulator which automatically varies the opening of the stack dampers and the speed of the induced draft fan to maintain the required pressure. This induced draft control consists of:

1. The pressure regulator;
2. The motor drive for the stack dampers;
3. The motor operated rheostat for varying the speed of the induced draft fan motor;

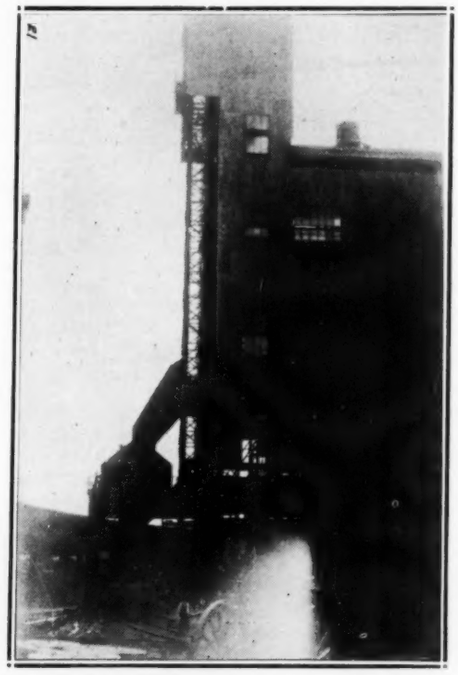


FIG. 21.

4. The reversing panels which are operated by the contacts of the pressure regulator.

The regulator is mounted high up on the setting near the point where the combustion chamber pressure is taken, thus eliminating the long connecting piping and is controlled from the main panel on the firing floor. It is completely enclosed and dust tight. Since its moving parts are very light and are held in position by a balance of forces rather than by a weight opposing a pressure, it is extremely sensitive to pressure changes. It moves in small successive steps, thus making the adjustments for all ordinary pressure changes without hunting.

The regulator consists essentially of a vessel for holding the oil and a bell and float, which are immersed in the oil bath and carry a vertical bronze shaft on the upper end of which are mounted 2 sets of contacts. Three magnet coils are mounted in the regulator so that their axis coincides with that of the vertical shaft. A short section of the

shaft is made of steel and one of the coils is mounted so that the lower end of this section occupies its core space so that when the coil is energized, its magnetic field tends to pull the steel section further into the coil and thus exerts a downward pull on the regulator shaft; the amount of downward pull depending on the amount of current in this range coil. The regulator float is hollow and is normally immersed in the oil for a greater part of its depth,

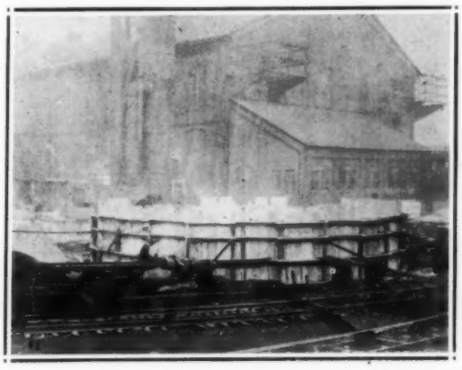


FIG. 22.

so that its buoyancy causes it to exert an upward push on the regulator shaft. The pressure connection from the combustion chamber is led to the underside of this bell, the top of which is exposed to atmospheric pressure so that a positive pressure will tend to lift the bell and shaft, and a negative pressure to lower it, the amount of pull exerted by the bell depends on the differential pressure between the point in the setting where the pressure connection is placed and the outside air.

In order to cause the control to move in successive steps and prevent hunting, a second steel section about 2" long is cut into the regulator shaft and 2 magnet coils so mounted that the upper end of this steel section moves in the core space of one, and the lower end in the core space of the other so

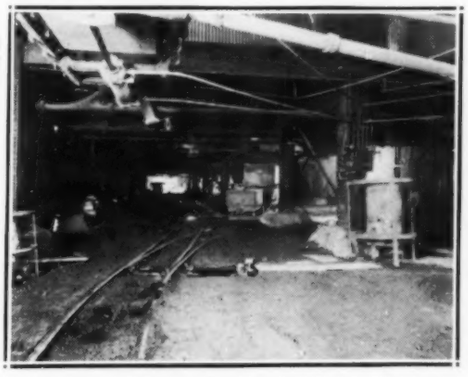


FIG. 23.

that the energizing of the upper coil tends to pull the regulator upward and the lower coil downward. The electrical connections of these coils are such that closing the upper set of regulator contacts energizes the lower notching coil which pulls the regulator shaft downward, opening upper set of contacts. When the position of the regulator float is changed by a small variation in combustion chamber pressure, the stack damper or fan speed is changed by a small amount before the notching coil opens the regulator contacts. If this change has not corrected the furnace pressure, the contacts are again closed with similar results. In case the combustion chamber pressure varies widely from the setting of the regulator, the pull of the notching coils to open the contacts is overcome and the movement of the stack damper or fan motor rheostat is continuous until the adjustment is nearly complete, when the notching coil again comes into action and the final adjustment is made in small increments, as previously described.

The dampers are operated by a standard 5 HP, 1150 RPM, shunt wound, motor, equipped with totally enclosing covers, applied in conjunction with a controller giving dynamic braking in the "off" position and one step of time limit acceleration. This time element relay is so adjusted that normal changes in damper setting are accomplished before the motor

FIG. 24.

is put on full line voltage. The one damper is motor driven through a gear reduction unit and is linked to the other damper by a double-link chain which keeps each damper in the same relative position.

The fan motor field rheostats are totally enclosed and have 2 faceplates, one of which is a vernier so arranged that a total of 2500 points may be obtained, but only about one-third of this number is in use at the present time.

The reversing panels carry the four magnetic contactors required to make and break the armature and field circuits of the damper motor and the motor for operating the field rheostat of the induced draft fan motor. These contacts are mounted back-to-back and are arranged to be totally enclosed and immersed in oil. The circuit is closed first on a carbon roller, which is held in position by a spring and is depressed when the switch is entirely closed. This roller serves as an arcing tip and since it rotates slightly it presents a new surface for each operation and wears evenly.

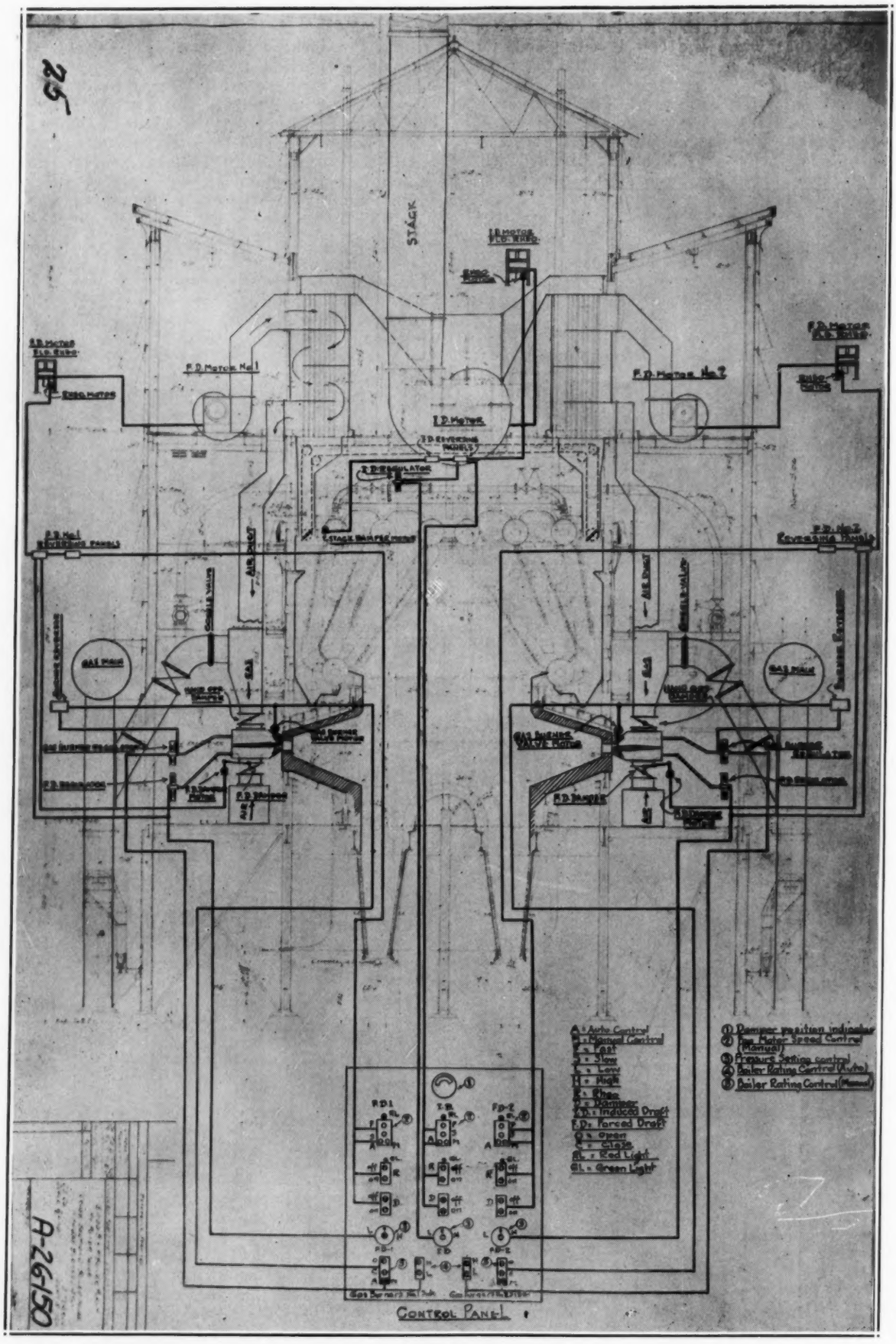

STACK
I.D. Motor
I.D. Reversing Panels
I.D. Regulator
F.D. Motor No. 1
F.D. Motor No. 2
F.D. No. 1 Reversing Panels
F.D. No. 2 Reversing Panels
Gas Main
Air Duct
Control Valves
F.D. Damper
F.D. Regulator
Gas Burner Valve Piping
A = Auto Control
M = Manual Control
F = Fast
S = Slow
L = Low
H = High
R = Rheo
D = Damper
I.D. = Induced Draft
F.D. = Forced Draft
O = Open
C = Close
RL = Red Light
GL = Green Light
1 Damper position indicator
2 Fan Motor Speed Control (Manual)
3 Pressure Setting control
4 Boiler Rating Control (Auto)
5 Boiler Rating Control (Manual)
F.D. 1
I.D.
F.D. 2
Control Panel
A-26150

FIG. 25.

The operation of this induced draft control is as follows:

The regulator is set to maintain zero pressure in the combustion chamber by adjusting the rheostat on the control panel, so that the pull of the range coil balances the upward thrust of the float, both upper and lower contacts will then be open The induced draft fan motor is started up from the master switch at the side of the control panel and allowed to run at its minimum speed with the motor operated field rheostat in full field position. Upon pressing the automatic button on the control board, the regulator picks up the control and adjusts the damper or motor speed to maintain the pressure for

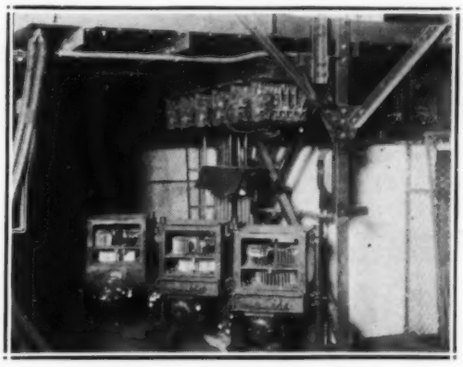


FIG. 26.

which the regulator is set. The "set" or combustion chamber pressure is changed by adjustment of the rheostat on the control panel which controls the current to the range coil. In case pressure in the combustion chamber is increased the float of the regulator will rise and close the upper contacts. This will energize the coils on the reversing panel which closes small magnetic contactors and starts the stack damper motor. The damper will then continue to open in small steps until the combustion chamber pressure has been reduced to the set pressure, or until the damper reaches its wide open position, when a limit switch cuts out the damper drive and at the same time closes the proper contactors on the reversing panels, to control the motor driven rheostat. The rheostat will move in the direction to increase the speed of the fan motor until the proper combustion chamber pressure is obtained, when the regulator float will drop and cut out the reversing panel. The fan motor will then continue to operate at this speed until the regulator contacts are again closed.

The forced draft fans are controlled by a similar regulator with the necessary appurtenances. The air dampers are operated by a ¼ HP, 1750 RPM, series wound, motor. To compensate for the variation of the air temperature a resistor having a negative temperature coefficient is mounted in the forced draft duct connected in series with the regulator range coil.

The Gas Burners are controlled in a similar manner—the principal difference being that the regulator is built to withstand gas surges without blowing the oil seal.

Figure No. 25 shows the schematic diagram of the control system.

Figure No. 26 is a view of some of the apparatus mounted on the fan floor.

Figure No. 27 is a view of control and instrument panel on firing floor.

The Plant is exceedingly well equipped with instruments which will enable the keeping of very complete records of plant operation. The total amount of feed water to the plant is metered and each boiler is equipped with an individual steam meter, in addition to which the total steam delivered to the line is measured by 2 main steam meters. CO_2 indicators and recorders are installed on each boiler and temperature and pressure indicators and recorders where necessary. The Blast Furnace gas is measured by a Republic Gas Meter installed in a 120" gas main which is 112.".5 I. D. The diameter of the meter throat is 93.".78. This is, to our knowledge, the largest meter yet installed on this service.

Although no official or acceptance tests have so far been made, the following table shows some of the operating figures for the month of March, 1927:

Average steam pressure	140#
Rating—average for gas fired boilers	206.6
Average for coal fired boilers	114.4
Average for coke breeze fired	145.6
Average for all boilers	181.3
Highest peak on individual boiler	349%
Highest peak on individual boiler, ½ hr.	327%
Temp. air to heaters average	70.4 deg. F.
Temp. of flue gases to stack:	
Blast Furnace gas fired boilers	420 to 570 deg. F.
Coal fired boilers	330 to 460 deg. F.
Coke breeze fired boiler	400 to 560 deg. F.
Temp. of flue gases leaving boiler:	
Blast Furnace gas fired boilers	680 to 730 deg. F.
Coal fired boilers	620 to 800 deg. F.
Coke breeze fired boilers	700 to 850 deg. F.

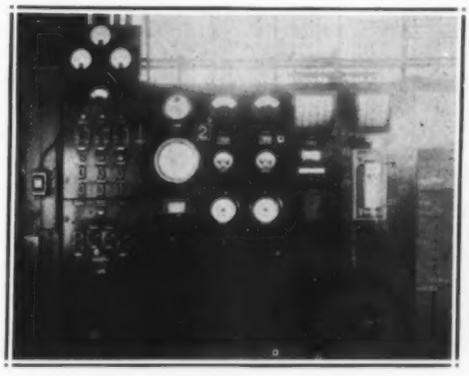


FIG. 27

Temp. of air to boilers:	
Blast Furnace gas fired boilers	460 to 560 deg. F.
Coal fired boilers	340 to 420 deg. F.
Coke breeze fired boiler	320 to 350 deg. F.
Temp. of fuel gas in main (average)	344 deg. F.
Pressure of fuel gas in main	5.5 to 9.8" water
Pressure of gas in burner box (average)	3" water
Pressure of air in burner box (average)	2.5" water
Negative pressure in combustion chamber	0.15" water
Fuel Gas Analysis Average—CO_2	13.52
CO	26.55
H_2	2.17
N_2	57.76

Analysis of gases at start of 1st pass:

CO_2—26.0 25.6 22.9 23.2
24.3 25.3 25.8 24.6; average for month—23.6

O_2— 0.4 0.2 2.3 2.0
0.4 0.3 0.2 1.6; average for month— 1.9

CO — 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0; average for month— 0.0

N_2—73.6 74.2 74.8 74.8
75.3 74.4 74.0 74.8; average for month—74.5
Average CO_2 in stack—19.5

PRINCIPAL DIMENSION AND EQUIPMENT IN BOILER HOUSE

Building:
Construction—steel,
Boiler Room—328′ long x 84′ wide
Distance from Ash Floor to Firing Floor—28′ 0″
Distance from Firing Floor to Fan Floor—54′ 6″
Width of front and rear aisle—19′ 6″
Width of aisle between boilers—13′ 8″

Boilers:
Make of boilers—Stirling
Type—Water Tube
Number installed—8
Water heating surface per boiler—22,250 sq. ft.
Water heating surface—total—178,000 sq. ft
Grate area projected area:—
(Underfeed stoker)—423 sq. ft.
(Chain Grate)—646 sq. ft.
Ratio of water heating surface to Grate area:—
(Underfeed stoker)—52.6 to 1
(Chain Grate)—34.5 to 1
Heating surface per sq. ft. of Boiler Room floor area—6.46 to 1
Furnace volume—12,000 cu. ft. (#1-#7)
11,500 (#8)
Ratio of furnace volume to water heating surface—1.85 to 1
Ratio of furnace volume to projected grate area (Underfeed stoker)—28.4 to 1
(Chain grate)—17.8 to 1

Tubes:—
Number—1,600
Size—3¼″
Length—Various
Gauge—#9

Safety Valves:—
Number—10
Size—4½
Type—Consolidated form DS

Blow-off Valves:—
Number—4
Size—2½″
Type—B&W low type in tandem with slow opening type Everlasting, monel trimmed.

Non-return valves—Golden-Anderson

Feed Valves:—
Number—4
Size—2½″
Type—Hancock angle type

Water Column:—
Number—4
Type—Reliance H&L Bronze mounted

Feed Water Controller—Copes

Boiler Pressure:—
Present—150#
Ultimate—250#

Type of setting—Solid fire brick
Construction of setting—22½″ Gen'l Refractories brick

Fuel:
Blast Furnace Gas.
Run of Mine Coal.
Coke Breeze.

Stokers:
3—14 Retort Frederick Underfeed by Combustion Engr. Corpn.
1—Chain Grate—by Illinois Stoker Co.
Number per boiler—1
Drive—(Underfeed):—
Number—5
Size—5 HP—335/1350 RPM
Type—Reliance Motors
(Chain Grate:)—
Number—2
Size—7½ HP, 340/1360 RPM
Type—Reliance Motors
Stoker performance—Guaranteed

Underfeed:—	Rating	Cu. Ft. Air/Min.	#s Fuel/hr.
	100	29,650	6,500
	150	45,200	12,830
	200	61,300	17,410
	225	70,500	19,900
	250	80,000	22,750
Chain Grate:—	100		10,000
	200		19,700
	275	100,000	29,000

Clinker Grinder:—
Type—Single Roll two sections
Drive—5 HP, 335/1350 RPM, Reliance Motor

Gas Burners:—
Type—Pressure
Manufacturer—Gas Combustion Co.
Number per boiler—4

Air Heaters:—
Number per Unit—2
Type—Tubular
Number of tubes—482
Heating Surface (in tubes)—9,667.5 sq. ft.
Sq. ft. Air Heating Surface—.869
Per sq. ft. water heating surface

Chimneys:—
Height above grate—114
Inside diameter—8 ft
How supported—On Fan Casing

Coal Handling:—
Supply received—By Rail
Capacity—100 tons per hour
Drive—Electric
Type—Skip Hoist
Stationary Conveyor
Traveling Conveyor and Scale Conveyor

Bunkers:—
Kind—Steel
Capacity—Coal—330 Tons
Coke—190 Tons

Coal Weighing—Richardson Automatic Scales

Ash Handling:—
Ash Car—Lakewood Engineering Co.
Tractor—Ellwell-Parker Elec. Co.
Skip Hoist—Link Belt Company

Forced Draft Fans:—
Number—16
Type—RB Double Inlet Radial Flow
Size—#4½
Manufacturer—Green Fuel Economizer Co.
Drive—20/100 HP; 700/1400 RPM, G.E. Motor

Induced Draft Fans:—
Number—8
Type—RR Design "B"
Size—#12
Manufacturer—Green Fuel Economizer Co.
Drive—80/450 HP; 300/600 RPM, G.E. Motor

Feed Water Pumps:—
Number—3—1,000 GPM
2— 500 GPM
Type—Jeansville
Size—3— 6″
2— 4″
Manufacturer—Worthington Pump & Mach'y Co.
Drive—Kerr Turbine

Feed Water Heaters:—
Number—4
Type—Open
Capacity—250,000# feed per hour
Manufacturer—E. T. Works

Soot Blowers:—
Number per Unit—32
Total—256
Material in Elements Nos. 1 to 5—Crodin
Material in Elements Nos. 6, 7 and 8—Steel
Type—Valve-in-head
Size—2″
Manufacturer—Vulcan Soot Cleaner Co.

*Electrical Developments In The Iron and Steel Industry**

BY ELECTRICAL DEVELOPMENT COMMITTEE

W. H. BURR, Chairman†

EACH year the problem of developing new equipment is given more serious consideration by electrical manufacturers, and naturally a larger financial investment is involved. In a report of this kind only such development as has reached a commercial stage is mentioned, which by the way is only a part of the vast amount of development work carried on by manufacturers of electrical equipment, some of which may never be of any commercial value. No effort has been made to cover any development which does not have a bearing on the application of electricity to the Iron and Steel and allied industries.

The information contained in this report was furnished by members of this committee, the writer's part has been simply classifying and compiling this information in such shape that it can be presented in the form of a report.

MAIN ROLL DRIVES

A complete list of main roll drives, now in service in United States and Canada, was published in the January issue of the Iron and Steel Engineer. It is interesting to note that there were purchased during the year 1926 one hundred and forty-eight main roll drives of over 300 HP. capacity.

There were eight motor driven main roll drives installed on Rail and Structural Mills, with a total of 13,000 HP., of which six were direct connected and two gear driven.

Twenty-eight Strip and Hoop Mill Drives were installed, seventeen of which direct connected, and the remainder geared. Only six of this number were AC motors, the others DC, ranging from 230 to 900 volts. Seventeen Sheet and Tin Plate Drives were purchased, eleven of which were AC, and six DC drives, all of these were geared.

Six Rod Mill drives were purchased, the largest of which was a 10" Wire Rod Mill motor of 3000 HP. capacity. Fourteen Sheet Bar and Skelp Mill drives were purchased, only three of which were direct connected, all the others were geared. Three of these were continuous Skelp Mills installed at Sparrows Point. These drives will be described later.

Thirty-two Merchant Mill Main Roll drives were installed. With the single exception of one drive these were all DC motors. Twenty-five Bar and Billett motors were purchased, six of which were direct connected, all others geared. Seven Cold Roll Mill drives were installed, all DC geared type.

The past year has witnessed the placing in service of an 8000 HP., 40/80 RPM, 700 volt, single unit, reversing motor as a drive for a 54" blooming mill. This motor has the highest rated continuous torque of any mill drive yet built and has a maximum torque rating of 2,500,000 foot-pounds; in service, it has developed a torque considerably in excess of this amount. It is of exceptional interest in that it is of the single armature construction, supplied with power from two 3500 K.W., 700 volt DC generators, connected in parallel. A simple method for the interconnection of the generators has been developed and perfected so that equal division of the load is assured, even under the most adverse conditions.

The first reversing mill equipment with parallel connected generators was installed less than three years ago, and there are now in successful operation ten equipments of a combined continuous capacity of 65,000 h.p. This development permits the most efficient design for motor and generators, and permits the use of the lower inertia, more efficient, single unit motor without sacrificing the advantages of the double generator equipment.

An interesting special installation of reversing motor equipment is the application of two 7000 h.p., 50/120 r.p.m. motors on the main rolls and two 2000 h.p., 57/163 r.p.m. motors on the edging rolls of the roughing and intermediate stands of a 52" universal structural mill. This is the first installation on record of separate reversing motor drives for the main and edging rolls of a universal mill. The field characteristics of the two motors were carefully proportioned so that the same relative rates of acceleration and retardation are obtained and the two motors operate in almost perfect unison. Means are provided in the control equipment to adjust the ratio of speeds of the two motors to compensate for changing roll diameters and differences in the drafts for the several passes.

On this same installation the screwdown control has been made with a number of automatic features. Limit switches are provided for each of the three screwdown motions, and the roll settings for each pass of the schedule are predetermined and set on these limit switches. The entire operation of the three screwdowns is then completely controlled from a single master switch which initiates the screwdown movements, the motions being accurately stopped at the predetermined positions by the limit switches. The use of these automatic features enables the operation of the mill with fewer men, and what is considerably more important, it assures the uniform drafting of the steel, and results in the production of a higher quality product.

There has been unprecedented activity in the purchase and installation of the tandem type of continuous mills for the rolling of strip, merchant and rod products. One of these installations which has been in operation for about a year, is a 20"—16" strip mill in the Chicago district. The six roughing stands are driven by a 1500 h.p., 705 r.p.m. induction motor; the two vertical edging machines are

*To be Presented at Annual Convention, June 13th to 18th, 1927, Pittsburgh, Pa.

†Elec. Supt., Lukens Steel Co., Coatesville, Pa.

each driven by a 100 h.p., 360/900 r.p.m., 600 volt, d.c. motor and the six intermediate and finishing stands are driven by individual 1500 h.p. and 1800 h.p., d.c. adjustable speed motors. The stands are arranged in a continuous straight line, and the mill is so equipped with furnaces, runout table, and coilers, that strip in exceptionally long lengths may be produced.

A 10" tandem mill for the production of rod, merchant and strip products is now being installed in the St. Louis district. The six-stand continuous roughing mill is driven by a 1500 h.p., 198/400 r.p.m., d.c. motor; stand 7, by a 600 h.p., 185/470 r.p.m.; stand 8, by a 600 h.p., 270/635 r.p.m.; stand 9, by a 720 h.p., 395/825 r.p.m.; and stand 10, by a 720 h.p., 480/1000 r.p.m. direct current adjustable speed motor. The use of billets up to 30 ft. long will enable finishing the rolled material up to several thousand feet long at speeds up to 2700 feet per minute. This material may either be coiled or cut to length by a flying shear and delivered on to a hot bed. Power for the operation of these five motors is supplied by a 2500 k.w., 600 volt, three unit synchronous motor generator set. Complete control of the electrical equipment, after starting the motor generator sets, is from a control desk mounted in a balcony overlooking the finishing end of the mill.

Developments in sheet steel rolling indicate that future installations will be along the line of continuous mills, especially for producing the heavier gauge material. A mill now being laid down in the Chicago district will be capable of producing sheet material up to 36" or more in width, and will have six 2500 h.p., 160/320 r.p.m., 600 volt, d.c. adjustable speed motors for the drive of the finishing stands. This is one of the heaviest powered of the continuous mills yet to be contracted for.

In order to secure the flat speed regulation demanded for tandem mill drive, the Westinghouse Company originated and perfected the use of separately exicted, compound wound, direct current motors, in which the main motor series excitation is supplied by a series exciter whose field is excited by the main motor armature current. An adjusting rheostat is inserted in the separately excited variable potential field circuit, and this rheostat is mechanically connected to the main motor shunt field rheostat so that the two rheostats are adjusted simultaneously. By suitably proportioning the resistance values, the series excitation can be made of the correct value to give essentially flat speed regulation at all speed settings. The first installation using this method of excitation and control was placed in service several months ago, and five other mill drives with eighteen motors are on order for similar service.

The motor equipment of a 10" merchant mill recently installed consists of a 1000 h.p., 200/600 r.p.m. motor for the roughing stands, a 1200 h.p., 300/500 r.p.m. motor for driving the intermediate stands and a 2000 h. p., 137.5/275 r.p.m. motor for driving the finishing stands. The motors are operated from a control desk and magnetic starting is used.

A very interesting combination mill consisting of a universal plate mill and a roughing structural and merchant stand was placed in operation in the Chicago district late last year. The motor equipment consists of a 3100 h.p., 70/150 r.p.m., 600 volt reversing motor driving a universal plate mill and roughing structural and merchant stand. The cross country merchant and finishing stands of this mill are driven by three 2000 h.p., 230/460 r.p.m., 700 volt adjustable speed motors. Power for the reversing motor and for the three 2000 h.p. adjustable speed motors is supplied by a fly-wheel motor generator set, consisting of a 6500 h.p., induction motor, a 100,000 pound flywheel and two 3000 k.w. generators.

The transfer and table motor controllers for the cross country mill are made to operate almost entirely automatically. Flag switches built into the roller tables operate to stop the table and start the transfer to move the steel to the entering position before the next stand. Here the transfer is stopped and the entering table started to enter the steel in the next pass. In this manner the various motions follow in the proper sequence, and the mill is operated with very little attention. In case of accident or on special schedules, the control may be made non-automatic and operated from master switches in the regular manner.

The development of continuous mills with individually driven stands is responsible for the notable increase in the use of direct current motors for main roll drives. Among new installations indicating this trend toward individual drive, there should be mentioned the 13-stand mill which will be installed by the Illinois Steel Company at their South Chicago Plant, this mill being driven by 13 motors totalling 10,500 h.p. At their Gary Works a 15-stand mill will have 11 motors totalling 6500 h.p., all of which are direct current adjustable speed.

At the plant of the Weirton Steel Company at Weirton, West Virginia, a new mill is to be installed which will be driven by three alternating current and five direct current motors, having a total continuous capacity of 16,000 h.p. Power for the five direct current motors will be obtained from two synchronous motor generators, each consisting of 1—4200 kv-a., 6600 volt synchronous motor and 2—1500 kw., 600 volt direct current generators. The five direct current motors are started simultaneously by Ward Leonard control, utilizing the voltage of the four direct current generators.

Another interesting example of a relatively new type of mill with individually driven stands is the strip sheet mill of the Columbia Steel Company, at Butler, Pa. The slabs are first rolled in a 27" reversing Universal Mill which is driven by a 5000 h.p. continuous-rated (12,500 h.p. maximum) 70/150 r.p.m., 900 volt, d.c. reversing motor. Power for this motor is obtained from a flywheel motor generator consisting of a 5000 h.p., 450 r.p.m., 6600 volt induction motor, 2—2200 kw., 450 volt generators, and 1—44 ton flywheel. The two generators are connected in series for supplying power to the 900 volt reversing motor. After leaving the reversing mill the steel passes in succession through four stands of rolls, each of which is a 4-high mill in which the working rolls are backed up by rolls of larger diameter. Each of the four stands is driven by a 2000 h.p., 200/400 r.p.m., 600 volt direct-current motor. Power for these motors is obtained from 3—3-unit synchronous motor generators, each consisting of 1—4200 kv-a. 6600 volt synchronous motor and 2—1500 kw., 600 volt generator.

A large reversing mill installation of considerable interest has recently been placed in operation at the Lackawana Plant of the Bethlehem Steel Company. The entire mill consists of three units: a 54" reversing blooming mill, a 48" reversing intermediate mill, and a 48" reversing finishing mill. The 54" reversing blooming mill is driven by a single unit 7000 h.p., 50 deg. C. rise, 40/80 r.p.m., 750 volt direct current motor. Direct current power is supplied to this motor from a flywheel motor generator consisting of 1—5000 h.p., 375 r.p.m., 6600 volt induction motor, 2—3000 kw., 750 volt generators operating in parallel, and a 50-ton flywheel. The 48" roughing mill is driven by two reversing motors, one of which is rated 7000 h.p. continuous at 65/100 r.p.m., 750 volts, and the other is a 1500 h.p. continuous, 65/225 r.p.m. direct current motor. Power for these two d.c. reversing mill motors is supplied from a flywheel motor generator consisting of 1—5000 h.p., 375 r.p.m., 6600 volt induction motor, 3—3000 kw., 750 volt generators, and 1—50-ton flywheel. The 48" finishing mill is also driven by two reversing motors which, with their motor generators, are duplicates of the machines required for the 48" roughing mill.

Other important reversing mill equipments which have been placed in operation include a 3000 h.p., 70/150 r.p.m. reversing motor which replaced an engine drive on a bar mill at the Indiana Harbor Plant of the Inland Steel Company. This company made a record change-over from steam to electric drive by removing the engine and its foundation, building new foundations for the motors and installing the motor and connecting it to the mill ready for operation in 122 hours from the time the mill was shut down.

The electrical equipment for 84" tandem plate mills has just recently been placed in operation at the Coatesville Plant of the Lukens Steel Company. Both roughing and finishing stands are driven by direct current reversing motors, the roughing motor being rated 1200 h.p. at 25/50 r.p.m., 330 volts. The finishing mill motor is a duplicate machine but rated 2500 h.p. at 53/80 r.p.m., 660 volts. The flywheel motor generator which supplies direct current power to these two reversing motors consists of a 3000 h.p., 600 r.p.m. induction motor, three duplicate 1050 kw., 330 volt generators, and a 25-ton flywheel. One of the generators supplies power to the roughing mill motor and the other two generators connected in series supply power to the finishing mill motor.

The Bourne Fuller Company, of Cleveland, Ohio, are installing a 4000 h.p., 58/140 r.p.m., 750 volt direct current motor to drive a 34" reversing blooming mill.

Several installations have also been made of adjustable speed induction motors using the Kraemer and Scherbius systems of speed control. Among these there should be mentioned two unusual Kraemer drives forming part of the electrical equipment for the 21" sheet bar and skelp mill at the Indiana Harbor Plant of the Youngstown Sheet and Tube Company. The first motor is rated 3600/1940 h.p., 290/156 r.p.m., and the second motor is rated 7500/4040 h.p., 250/134 r.p.m. These drives are unusual in that the direct current motor which is a part of the Kraemer system and is ordinarily direct connected to the induction motor is in each of these cases used as part of a synchronous motor generator which supplies power to 3—2000 h.p. direct current finishing stand motors.

The Inland Steel Company purchased for their Chicago Heights Plant 2—1000 h.p., 225/168 r.p.m., 4000 volt induction motors each with Kraemer speed control equipment for driving rail re-rolling mills. For their Indiana Harbor Plant to drive a 24" sheet bar mill this company also has installed a Scherbius controlled induction motor rated 3000/2250-1500 h.p., 500/375/250 r.p.m., 2200 volts.

The Buffalo Steel Company of Tonowanda, N. Y., have replaced engine drives on a rail re-rolling mill by two Scherbius controlled induction motors rated 1350/1000 h.p., 214/161 r.p.m., 4400 volts.

The Bethlehem Steel Company is installing at its Sparrows Point Plant a continuous sheet bar and skelp mill having three different types of driving motors. The first 8 stands will be driven by synchronous motors, No. 1 being of 4000 h.p. capacity at 83 r.p.m. and No. 2 a 6500 h.p. motor at 187 r.p.m. The next 3 stands will be driven by an adjustable speed induction motor with Scherbius speed regulating equipment, the motor being rated 6700/5000/3320 h.p. at 500/375/250 r.p.m. This is the largest Scherbius controlled induction motor in this country. The finishing stand is driven by a 2600 h.p., 320/275 r.p.m. direct current motor.

The use of two synchronous motors on the mill just mentioned and the recent purchase of a 5000 h.p., 240 r.p.m. synchronous motor by the Standard Seamless Tube Company for driving a piercing mill follow the successful application and operation of the 9000 h.p. synchronous motor at the Cleveland Plant of the Corrigan McKinney Steel Company. This motor has now been in successful operation for about a year and has met all of the demands of the mill both starting and running without difficulty.

Another contribution during the last year towards the advancement in the art has been the installation of a 1500 h.p. synchronous motor direct coupled to a 21" Tube Mill at Gary. This motor is started directly across the line and brings the mill up to speed, reverses, and has dynamic braking. In fact, it operates the mill in exactly the same way as was formerly accomplished by wound rotor induction motor. This equipment has been in operation since the first week of January and has proved entirely satisfactory. This is simply another indication of the growing application of synchronous motors to drive steel mills.

STEEL MILL CRANES

For a number of years there was very little development in Steel Mill cranes, but within the last two years considerable work has been done along this line. The Standardization of ball and roller bearings has opened up a new field in crane development. One manufacturer alone has in service over forty-five Standard Steel Mill cranes, ranging from 5 to 40 tons, which are equipped with roller bearings.

150 Ton, 4 Girder type Ladle Cranes have been built during the past year, equipped throughout with anti-friction bearings.

One worm driven interlocked drum Ladle Crane has been put in service. This crane is also equipped with roller bearings.

Two low type stiff leg soaking pit cranes have been installed with anti-friction bearings.

A Floor Type OH Charger is in successful operation on which is installed a worm driven hoist and cross travel. Anti-friction bearings are used on this crane also.

Another development along this line is a screw type ingot stripper used for stripping ingots from inverted Gathman type moulds. This stripper consists of four units which can be operated together or independently. Eight molds are carried on each car and this car is run through the stripper which is mounted on the floor. The clamping rams on the stripper are located above the top of molds and are connected to one of the stripper nuts. The bull nose for shoving the ingot out of the mold is located in a slide underneath the car. A large link is connected to one of the stripping nuts for pushing the bull nose up through a hole in the car and through a hole in the bottom of the mold.

Each stripper unit is driven by a 65 h.p. motor and the capacity of each unit is 100 tons. After the car is spotted in the stripper and the single control lever is thrown to the on position the upper clamping rams lower and clamp the molds while the links swing into position underneath and raise the bull nose up, thus shoving the ingot out of the mold. Upon reversal of the control lever all units return to their original position. In case any one unit should become disabled this unit can be cut out and not interfere with the operation of the other units.

A test was recently made using two units of the stripper and 120 ingots were stripped in 20 minutes. This stripping process, however, only consists in loosening the ingots in the molds, the ingots afterwards being lifted out with tong cranes.

Closely allied to this development is the application of automatic control to furnace doors, pit covers, and even transfer cars, so that the crane operator has the operation of this equipment absolutely under his control, thus eliminating considerable labor charge, and actually speeding up operation.

POWER HOUSES

The capacity of turbine generators for steel mill power stations continues to increase. The Illinois Steel Company has purchased for its Gary Plant a 30,000 k.w. machine. This will supply power at 6600 volts, 25 cycles. The Tennessee Coal, Iron and Railroad Company will install 2—20,000 k.w. turbine generators, and another unit of the same size has been purchased by the Bethlehem Steel Company for installation at their Sparrows Point Plant.

During the past year an order was placed for the largest steam driven Turbo-Blower for blast furnace operation in one of the country's largest steel plants. This unit will deliver 60,000 cu. ft. of air normally at 18-lbs. gauge or a maximum of 80,000 cu. ft. at 35-lbs. gauge. The driving turbine is a 10,200 h.p. combined unit taking steam at 200-250 gauge, 200°F. superheat and condensing at from 28 to 28½ inches vacuum.

Another outstanding development during 1926 is the installation of numerous Mercury-Arc Power Rectifier sets for substation operation attended with great gains in efficiencies, maintenance and silence in operation. The total capacity of these power rectifiers already installed is approximately 50,000 k.w.

In rebuilding old switching stations it is often desirable to secure increased rupturing capacity in oil circuit breakers in the same space as occupied by the older breakers. Also on new installations, it is necessary to keep the space requirement to a minimum. These conditions have been met by the development of a line of common tank oil circuit breakers having very much higher interrupting capacity than older types which occupy about the same space. The common tank design, in which the three poles are installed in the single tank, gives large oil volume which assists in efficient arc rupture. Insulating barriers separate the poles.

One of the most notable advances in circuit breaker design during the past year has been the perfecting of the non-closable on overload feature to apply on air break circuit breakers that are controlled from a remote point by means of an electromagnetic device. With this added feature it becomes impossible for a circuit breaker that is inadvertently closed upon an existing short circuit, or overload, to advance through the entire closing cycle. Immediately upon encountering an abnormal condition in the circuit, the contact carrying members are mechanically tripped free, in order that they may return to the open position before the electrical equipment, or circuit breaker itself, may be damaged. This circuit breaker construction, which is known as the trip free at any point of the closing stroke, is proving of great value in both the industrial and in the public utility field.

Another development is Automatic Power Factor Regulating apparatus for use with Synchronous motors. The Regulator varies the motor field rheostat in order to maintain the corrective power factor within desired limits.

A Type ICC Relay, which visibly and audibly indicates and counts oil circuit breaker operations has been developed.

UNDERGROUND CABLES

The steady consistent improvements in the design, materials and manufacture of underground cables noticeable during the last year has been of particular benefit to Electrical Engineers connected with the Steel Industry by insuring continuous operation of the plants. Materials and methods used recently by the manufacturers have materially decreased the dielectric losses and eliminated voids in the insulation by means of revised vacuum processes.

A noticeable advance involving a new principle developed by D. M. Simons of the Standard Underground Cable Company is the machine made joint on single conductor cables operating at 60 kv. up to 132 kv. which has largely been responsible for increased confidence of Engineers in satisfactory operation of circuits at these higher voltages. This new principle in making cable joints eliminate the personal equation from the joint by applying a long wide metallized roll of impregnated paper to the cable in the joint by means of a machine mounted in place in the manhole and clamped to the two ends of the cables. Cable compound or oil is constantly poured onto the wide roll on which the tension is steadily maintained by bars on the machine. The final result is a solid, compact joint,

free from air and of a quality heretofore unattained for breakdown strength. Research is being pushed on a machine to make three-conductor joints on belted and type "H", (with metal foil on each insulated conductor) cable.

Among the new potheads envolved of late is the Barrier type high-voltage terminal, with oil filled ground shield, increasing the flash over and puncture voltages. The flaring metallic shield joined to the end of the cable sheath relieves and redistributes the stresses. The puncture strength of the oil is increased by breaking it up into a number of films by concentric micarta tubes over the conductor insulation, an oil reservoir of clear glass at the top affords easy inspection of oil movements.

LIFTING MAGNETS

Some applications of lifting magnets have been made which are rather unusual and are given as a suggestion which may help solve some of the problems involved in present steel mill practice.

Magnets have been sold to charge a large Cupalo continuously operated, the magnets being surrounded by flame. This installation replaces from 4 to 6 men on each of three turns per day.

Rectangular magnets are handling large rolls of hot strip steel, temperature 1000° to 1300°F.

2—65" Round magnets and 4—26"x42" Rectangular Rail magnets are being used on 2—25 ton beam cranes mounted on rails running the length of the steamer Lagonda, of the Interlake Steamship Company, Cleveland, the round magnets to handle scrap and pig iron and the rail magnets to work in pairs and used for loading and unloading rails. It is understood this magnet equipment saves the boat about 30 hours time at each end of the trip.

A Lifting Magnet Controller with small master equipped with short levers to be operated by finger or thumb has been introduced which has two advantages.

First: The master is so small it may be attached by a bracket to the operating lever of the hoist control or to the throttle of a locomotive crane and so save the operator's time.

Second: There is a heavy rib protecting the operating levers so that they cannot be depressed accidentally, thus contributing to safety.

This development was inspired by the killing of an Assistant General Superintendent due to the premature dropping of a skull cracker ball, caused by the operator leaning out of the window to reply to the Assistant Superintendent who had entered the enclosure and called to him.

MAGNETIC BREAKERS

More development has taken place in this time than has for some years past.

A new DC brake, known as the "3-C" brake, incorporating all the good features of a band brake, and certain features of the later type shoe brakes have been put on the market, and is being well received.

A brake of the same general design has been fitted with an AC coil, and mechanism which is of a new design also.

Improvements have been made to the type M shoe brakes so as to increase the life of the wearing parts. Adjustments have been simplified, and changes made in the magnetic structure of these brakes.

The type WB Shoe Brake which has been undergoing development for two years was put on the market. An important feature of this brake is the ease with which a motor armature can be removed without disturbing any of the brake adjustments and without dismantling the brake in any way.

It is gratifying to note that magnetic brakes are now available which are operating very satisfactorily.

AUXILIARY MOTORS

During the past year Direct Current motors were furnished on a Pipe or Tube Mill for Kellogg Steel Co., of Jersey City, N. J., on which one motor drives the top roller and the second motor drives the bottom roller.

Variable speed, variable voltage, variable cycle, roll out motors, using shaft extension on each end, with ball bearing on each end shield were installed at the runout tables on 9—12" Mills at the McDonald Works, of Carnegie Steel Co. At the Gary Works of the Illinois Steel Co. three-hundred of these roll out motors, all fully enclosed and equipped with fire proof coils, are to be installed in strip mills.

A line of flame proof motors has been developed, the principal application of which so far has been in coal mines.

One of the manufacturers of auxiliary motors claims to have made more improvement in motor design in the last twelve months than in any combined five or ten year period in his history.

MISCELLANEOUS

Another new development during the past year, of interest to steel mill Electrical Engineers, is the protection of switch contacts from the corrosive action of gases. This is accomplished by applying a special neutral alloy to the contacts and blades.

The conductivity of this alloy is only slightly less than that of copper and the contacts of switches are made slightly larger to compensate for this.

The experimental work has been conducted on this alloy for considerable time, and it has proven successful under the worst gas conditions. As an example, switches were placed in the by-product department of the coke plant of one of the large steel companies. After six months there was no discoloration of the protected surfaces, and only 2°F. additional temperature rise over that shown before being exposed to the gases.

Installations have been made in several lines of industry where gas conditions have previously caused corrosion and consequent heating of switches.

Considerable progress has been made in the development of porcelain supports and fittings for pipe structures.

Another new development is the Obround Condulet. The wedge nut fastener securely holds the cover on the wiring devices, and it cannot become loosened by vibration. This fitting possesses many distinctive features and is a valuable addition to the condulet line.

Edgewound Resistor Banks were furnished to take the place of cast grid resistors used in the field circuit of a large motor direct connected to the main rolls of a rolling mill.

"Nickel-Alloy" Resistors were perfected and put on the market during the past year. "Nickel-Alloy" Resistors are inter-changeable with certain Cast Grid Resistors and are non-breakable in service. They have all the advantages such as rugged terminals, ease of locating terminals, ability to provide correct carrying capacity on each step, and other desirable features of ordinary cast grid resistors and they can be counted upon to withstand the most severe treatment without breaking.

CONCLUSION

In conclusion the committee wishes to express its appreciation to all those who have furnished information given in this report, and we sincerely hope that the information given may in some manner be the means of reducing cost and increasing tonnage output in the steel industry, which after all is the goal for which all those connected with the steel industry are striving.

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*Factors Governing the Design of Roller Bearings for Roll Necks**

By F. H. BUHLMAN, M. E.†

THE process known as rolling of ferrous metals is undoubtedly one of the most important methods of working metals to a definite shape mechanically. The very active interest shown by manufacturers of rolling mill equipment, as well as users, in the application of anti-friction bearings to roll necks is in itself proof of the progress made in this direction. The advantages of anti-friction bearings in roll necks are numerous, the most important being, first, maintenance; that is, reduced cost of upkeep, second, greater accuracy in rolling due to the very accurate tolerances of anti-friction bearings, therefore increase in production; and third, considerable saving in power. However, it must be understood that the first cost of installing anti-friction bearings is high, as compared to plain babbitted bearings. In addition, the cost of replacing anti-friction bearings, if same fail, due to faulty installation, is also considerably larger, so that obviously greater precaution should be taken regarding the adaptation of these bearings for roll necks than has been done in the past with plain bearings. There is no question but that the load conditions resulting from the rolling process are very severe, the available space being at the same time very limited. Unfortunately, very little information is available regarding magnitude, as well as variation of these conditions. Consequently, a knowledge of the exact changes taking place in rolling ferrous metals and of the forces which are brought into play is of utmost importance, as this knowledge alone places engineers in a position to effect improvements like the application of anti-friction bearings and to take full advantage of this progress from a commercial standpoint.

One of the first questions which is of vital interest to the mill operator is of course as to the power required to drive a mill. This question has been cleared up by a considerable number of investigations and there is no question but that the application of anti-friction bearings will be a further progress in this direction. However, there still remains another very important question, particularly important from an anti-friction bearing standpoint, namely, ascertaining of the pressures exerted by the material on the roll and the resulting bearing reactions during the process of rolling. These pressures not only determine the design of mill housing, diameter and length of rolls, permissible reduction in each pass and arrangement of consecutive passes, but are obviously of utmost importance in the selection and design of the proper anti-friction bearings (that is, roller bearings, since for these conditions only this type of anti-friction bearing appears to have the proper qualifications.) Unfortunately, the "roll drafting," that is, reduction permissible in each pass, as well as arrangement of passes, in the past has very often been done by the "rule of thumb" method, with satisfactory results it is true, but there is no doubt that it could be improved at least and this is merely mentioned here because of the influence this has on the load conditions, and especially the change in conditions during one pass, as well as from pass to pass. It is not necessary to point to the calamity of failure of bearings or rolls as consequence of the material being stressed too highly. These cases are not only very unfortunate, but they remain a challenge to engineering. They can only be prevented if the pressures on the rolls during each pass are definitely known and this knowledge thus formulated has to guide the designer in his calculations and construction. From a commercial and operating standpoint, the importance of these failures lies not so much in the cost of the material that has to be replaced, as in the waste of having the mill stand idle while they are replaced, as well as the uncertainty of replacing this material without determining the cause of the failure.

From the two main load conditions on a roll, namely, torsional and bending, the first can be predetermined with sufficient accuracy from known data. The bending, however, is not so easily ascertained and is of a more complicated nature.

In a mathematical solution, too many variable factors would have to be considered, so that such a solution becomes by far too complicated and therefore useless. For instance, the flow or displacement of the metal, not only with regard to change of size, but also change of shape, renders the determination of the pressures acting on the rolls extremely diffi-

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cult, so that experimental determinations are less complicated, at the same time yielding better results. Several methods can be used without difficulty and especially without interfering with the operation and the output of the mill: For instance, the strain exerted by the roll on the housing could be measured by means of strain meters and the load producing this strain deduced from it. Another method similar to the method used in determining the hardness of materials by means of indentation produced by an applied load has also been applied. The disadvantage of this method lies in the fact that the change of load conditions during one pass are not so readily determinable. One of the most satisfactory methods was published as early as 1910 by Dr. Puppe of Dortmund, Germany, in the "Memoirs of the Carnegie Institute." It consists of two hydraulic cylinders fixed on the top of the top chocks which form the bearings for the upper roll. The cylinders are equipped with closely fitting pistons resting against the screwdowns. The pressure is transmitted by means of a mixture of water and glycerine through a very small tube to the pressure gauges. Ordinary manometers or more elaborate recording gauges, or both, may be used.

The recording pressure gauge described by Dr. Puppe consists of a so-called Bourdon-spring and through a system of levers with pencil attachment, a pressure diagram is obtained on a roll of paper arranged on a clock-driven drum. The pressure is thus plotted as ordinate against time as abscissa. Of course, the determination of time is quite important and can be checked by some independent secondary device. In order to obtain correct results it is also important of course that the axis of the cylinder is at all times normal to the shaft axis and this can be obtained by means of ball and socket arrangement. The readings of the pressure gauge should be corrected due to friction of the piston rings, packings, etc. and correction factors can easily be obtained by gauging the apparatus in a testing machine with known load application. Temperature readings should also be taken at intervals in order to make the test results as complete as possible, and the same is true of course for the speed of the rolls. Comparison of the different readings for pressure, temperature and speed in connection with the reduction of cross-section of the rolled material is very interesting.

The pressure curves obtained from tests of this nature have exceedingly interesting characteristics, the study of which and the conclusions arrived at are of great importance for the intelligent application of roller bearings for this service. A series of pressure curves obtained from tests made by Dr. Puppe are published in the "Memoirs of the Carnegie Institute" and should prove of great interest, although obtained with a steam engine driven mill. It is not possible to enter into a detailed discussion of these curves, although they are very interesting, and the following discussion is limited to a few of the most striking characteristics.

First, the irregularity of the pressure curves, even for passes for which the draft is practically the same throughout, is a very peculiar feature which is probably due to the variations of speed during the rolling process. For the majority of passes investigated the pressure increases very rapidly to a maximum; it then decreases slowly during the duration of the pass. Toward the end of the pass the pressure increases again to a peak value and falls very rapidly at the end. Considering the short duration of a pass, the fluctuation of pressure just described means that the bearings will be subjected to a cycle of rapidly increasing and decreasing forces and, as is well known, the strains imposed on the material are considerably larger than for continuous, uniform load conditions. From this it also follows that the maximum loads should be considered as a criterion for the proper dimensioning of the bearings and not, as is often believed, the average load conditions.

The fact that the pressure curves bend downward in the center of the pass, although the speed is then at its maximum, is because the end of the ingot cools more rapidly than the other part, thus causing the pressure to raise toward the end, although the speed is then decreasing. Even should the mill stop in the middle of the pass, that is, the material come to a rest, the pressure will not decrease to zero but still have a considerable magnitude due to the elastic behavior of the material. It is also obvious that conditions will be particularly bad for the last passes, since for the first passes the temperature is quite high and the material is more of a spongy type; therefore reducing the resistance to displacement considerably.

These results are not only very important to determine the bearing reactions, but they should prove of great interest in determining the factors in the rolling process producing these pressures. Power, displaced volume, pressure, temperature, etc., can thus be correlated to be of great value to the designer in selecting size of rolls, bearings, etc.

Of course, the results of such an investigation do not at first appear to be uniform, due to a large number of auxiliary factors which cannot be included for the sake of simplicity, such as errors in measuring the section between consecutive passes, wear on rolls, bending, strain and deformation of frame, screwdowns, etc. The measuring of the pressure can be considered as accurate within practical limits; however, the relation of pressure to displacement, temperature, etc., is not obvious at first. Upon further investigation it is apparent, however, as Puppe says, that "The relation between the volume displaced per second, the pressure on the rolls and the temperature is quite definite and appears to follow a natural law." This can be represented graphically in plotting the ratio

$$\frac{\text{Displaced volume per second}}{\text{Pressure on Rolls}}$$

as ordinate, against temperature as abscissa.

A similar curve is published in the Iron and Steel World No. 1 by J. D. Keller. There the unit pressure is plotted as ordinate, against the compressive rate; i. e., the ratio

$$\frac{\text{Compression Velocity (inches per second)}}{\text{Thickness (inches)}}$$

as abscissa, for various rolling temperatures ranging from 1900 to 2200 degrees Fahrenheit. Unit pressure is understood as the pressure in pounds per square inch of projected contact area between roll and material. Compressive velocity is understood as the velocity at which the material is reduced from the thickness before rolling to the thickness after rolling, or, it is the ratio

$$\frac{\text{Reduction of Thickness}}{\text{Time required to Pass through the Contact Angle}}$$

With known contact angle and speed of rolling, above ratio can easily be figured for each pass.

Thus, if the operating conditions of existing mills are investigated experimentally, as described above, or by any other sound method, which can be done without interfering with the operation and output of the mill, and the results formulated or correlated by means of graphical representation, conditions for a new mill can then be deduced from it with sufficient practical accuracy. Bearings, as well as other parts of the mill, can then be designed to meet these conditions, thus eliminating a great amount of guessing and uncertainty, which are always connected.

DESIGN OF BEARING

From a standpoint of design, the application of roller bearings to rolling mill service differs from conventional design in that extremely high load conditions are combined with very serious space limitations. The type of roller bearing which has proven very successful in heavy duty service is practically excluded for mill type service because, due to its short roller, (length about 1 to 1½ times the diameter) a bearing of large diameter would be necessary to meet the load conditions. The use of such a bearing is not possible, since the permissible outside diameter of the bearing is determined by the diameter of the roll. At the same time, the roll neck has to be as large as possible in order to withstand the stresses imposed on it. Available space in radial direction left for the roller bearing is therefore very limited and, in order to obtain the necessary capacity, the bearing has to be made rather long. As is well known, the use of very long rollers involves some difficulties, and the capacity does not increase in the same proportion as the length, since any misalignment of the rollers in reference to the roll axis will reduce the contact area between rollers and races. For this reason, the Rollway Bearing Company divides the bearing length into two or more roller assemblies, with the result of obtaining the maximum capacity for a given length, together with the highest accuracy.

A typical installation is shown in Figure 1. An interesting feature of this design is the thrust bearing which takes the axial thrust due to misalignment of the rolls or due to section rolling. This is a Rollway Simplified Double-acting Thrust bearing taking the thrust in either direction, although having only one roller assembly. This permits the use of one bearing at one end of the roll only, leaving the other end free to expand. This bearing was originally developed by the Rollway Bearing Company for propeller shafts of marine Diesel engines, in which location they have proven very successful. There is no doubt but that they will give just as satisfactory service in rolling mills—(the more so because thrust conditions are of secondary importance) and will at the same time materially reduce the initial cost of the installation.

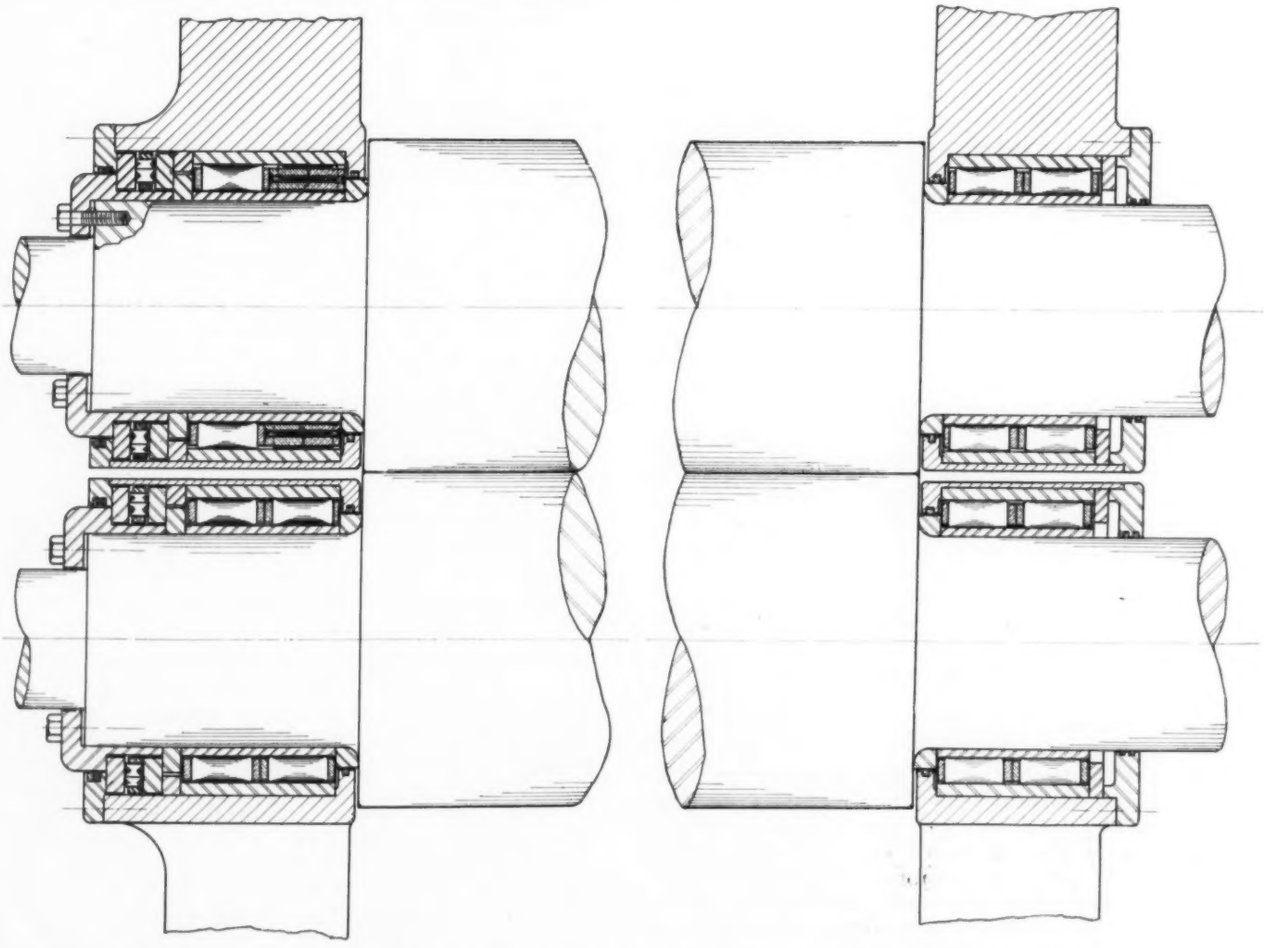

FIG. 1—Note that the thrust bearings are double acting and will take the thrust of the roll in either direction.

The limitations of design, together with the severe radial load conditions, make it obvious that the available bearing space should be used most efficiently; i. e., the maximum resistance opposed to the radial load, and this is obviously accomplished with greatest certainty by the cylindrical type of rollers, giving the maximum contact area in a direction normal to the direction of the load, thus giving minimum stresses for a given load. The so-called combination radial and thrust bearings, while very satisfactory whenever load conditions are comparatively light, have however very serious limitations for heavy duty service.

COMPUTATION OF STRESSES ACTING ON BEARING

Let us consider two parallel cylinders, of radius r_1 and r_2 respectively, in contact under the action of a compressive force P distributed uniformly in a plane through both axes of the cylinders. This is the fundamental problem, one cylinder representing a roller, the other the race. The width, 2a, of the contact area generated between the two cylinders under the action of load P is given by H. Herts as:

$$a = 2\sqrt{\frac{P}{\pi \times L}\,\frac{\frac{1}{E_1}(1-V_1^2)+\frac{1}{E_2}(1-V_2^2)}{\frac{1}{r_1}+\frac{1}{r_2}}} \qquad (1)$$

where:

E_1 and E_2 = the modulus of elasticity for cylinders 1 and 2 respectively.

V_1 and V_2 = Poisson's ratio for cylinders 1 and 2 respectively.

$\frac{1}{r_1}+\frac{1}{r_2}$ To be taken for positive contact, i. e., the cylinders being outside tangents, or

$\frac{1}{r_1}-\frac{1}{r_2}$ If the smaller cylinder is inside tangent to the larger cylinder.

Positive contact, that is, the contact between roller and inner race, obviously gives a smaller contact area and heavier stresses than negative contact, that is contact between rollers and outer race. It will therefore be sufficient to investigate only the more unfavorable condition.

This equation is dimensional, i. e., good for any consistent system of units.

Hertz' equations are based on assumptions, the most important of which are:

(1) The contact area is small compared with the main dimensions of the cylinders.

(2) Only stresses normal to the contact surface are considered, it being assumed that there are no shearing stresses acting on this surface.

(3) The stresses are within the limit of elasticity.

How far these assumptions, and particularly the last one, correspond to actual behavior will be discussed below.

The Stresses. With assumption (3) the deformation will follow Hooke's law. Therefore, the stress distribution over the contract area in a plane normal to the axis can be represented by the segment representing the deformation of this plane as shown on Fig. 2.

Load P could then be expressed as the product of length L of the cylinder into the area of the segment with chord 2a and height $\sigma_{max.}$

This expression however is too complicated for practical purposes, and the segment can—for the sake of simplicity—be replaced with sufficient accuracy by either a half ellipse or a segment of a parabola.

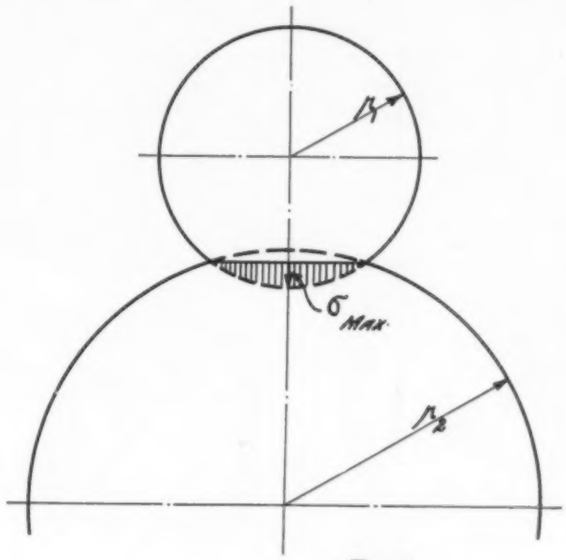

Fig 2

For the first approximation, Load P, would then become:

$$P = \frac{\pi \times a \times \sigma_{max.} \times L}{2} \qquad (2)$$

And for the second approximation

$$P = \frac{2}{3} \times 2a \times \sigma_{max.} \times L$$

Let, for the sake of argument, the stress distribution be according to the first form. Then, by introducing into equation (1) the value of "a" from (2) and at the same time assuming that

$$V_1 = V_2 = V$$

The maximum stress on the contact area can then be expressed as (3)

$$\sigma^2_{max.} = \frac{P}{\pi \times L} \times \frac{\frac{1}{r_1}+\frac{1}{r_2}}{(1-V^2)\left[\frac{1}{E_1}+\frac{1}{E_2}\right]}$$

or with V = .3

$$\sigma^2_{max.} = .35\,\frac{P}{L} \times \frac{\frac{1}{r_1}+\frac{1}{r_2}}{\frac{1}{E_1}+\frac{1}{E_2}}$$

Then, if the maximum load P on the roller can be expressed by the load on the whole bearing, the maximum stress can be computed and discussed.

Load Distribution. For ball bearings the maximum load P on one ball is according to Stribeck:

$$P = \frac{5\,W}{n}$$ where n = number of rollers
W = total load on bearing.

For a roller bearing P will be less, because—as has been shown by mathematic analysis and by test—the deformation δ i. e., the relative approachment of the races is approximately a linear function of the load, i. e., $\delta = kP$, while for ball bearing it is

$$\delta = kP\ 2/3$$

Let one roller be directly in the line of load and the other at angles Θ_1 2Θ . . etc., to each side. Let it be assumed that journal and bearing housing are rigid bodies. If then δ_0 is the total vertical compression it follows that this must be the same for all rollers in the loaded half (see Fig. 3).

Then for the deformation in radial direction

$$\delta_1 = \delta_0 \cos. \Theta$$
$$\delta_2 = \delta_0 \cos. (2\Theta) \quad . \quad . \text{ etc.}$$

and:

$$\delta_0 = k\ P_0$$
$$\delta_1 = k\ P_1$$
$$\delta_2 = k\ P_2 \quad . \quad . \quad . \text{ etc.}$$

where P_0—P_1—P_2. .etc., are the load components in direction δ_0—δ_1—δ_2. . . .etc.

therefore $\frac{P_1}{P_0} = \frac{\delta_1}{\delta_0}$; $\frac{P_2}{P_0} = \frac{\delta_2}{\delta_0}$ etc

The load components in direction of the total load become:

$$Pv_1 = P_1 \cos \Theta = P_0 \frac{\delta_1}{\delta_0} \cos \Theta = P_0 \cos^2 \Theta$$

$$Pv_2 = \text{— — — — — — } = P_0 \cos^2 (2\Theta)$$

and hence the total load

$$W = [\ P_0 + 2\ P_0 \cos^2 \Theta + 2\ P_0 \cos^2 (2\Theta) + \text{- - -}]$$
Limit $\Theta = 90°$

$$W = P_0 [\ 1 + 2\ (\cos^2 \Theta + \cos^2 (2\Theta) + \text{- - - -})\ ]$$
Limit $\Theta = 90°$

where $\Theta = \frac{360}{n}$

n = number of rollers

If this equation is evaluated for different values of n it will be seen that approximately

$$W = \frac{P_0 \times n}{4} \qquad (4)$$

The magnitude of compressive stress to which the material may be safely subjected of course depends upon the physical properties of the material used. These properties are different for compression and tension, and it is a mistake to base the load capacity of a bearing upon the tensile properties of the material, although this of course would be on the safe side, since the compressive strength of material is considerably higher than tensile strength. The ultimate comprehensive strength has been determined experimentally by various investigators. Stribeck's three-ball tests are well known and used by practically all ball bearing manufacturers. The corresponding ultimate strength (pounds per unit contact area) for rollers is somewhat less, of course, although it may not seem so at first glance. This can be seen from the following reasoning:

Consider an element of the loaded roller near the centre of contact area, with limiting planes parallel to the planes of the reference system: X-axis parallel to roller axis, Z-axis in direction of load normal to X, and the Y-axis normal to the XZ plane.

The unit load on plane XY in direction Z is, σ. According to Hertz, the reaction of the surrounding elements on planes XZ is $.8\,\sigma$, parallel to Y. The roller is free in the direction X, therefore there are no stresses acting on planes YZ.

Then the unit deformation in direction Z becomes

$$E_r = \frac{1}{E} (\sigma_r - \nu \times .8\ \sigma_r) = \frac{\sigma_r}{E} \times (1 - .3 \times .8)$$

$$E_r = .76\ \frac{\sigma_r}{E}$$

On the other hand, if a similar element of a ball is considered, the reaction of the surrounding elements is $.8\ \sigma_c$ on plane XZ as well as on plane YZ, so that:

$$E_c = \frac{1}{E} (\sigma_c - 2 \times \nu \times .8\sigma_c) = \frac{\sigma_c}{E} (1 - .48)$$

$$= .52\ \frac{\sigma_c}{E}$$

Assuming that the deformations follow Hertz' law, the ratio of maximum stress for ball and roller, based on the same fatigue, would then be:

$$\frac{\sigma_r}{\sigma_c} = \frac{.52}{.76} = .685$$

The considerably larger total capacity of a cylindrical roller, as compared to a ball of same diameter,

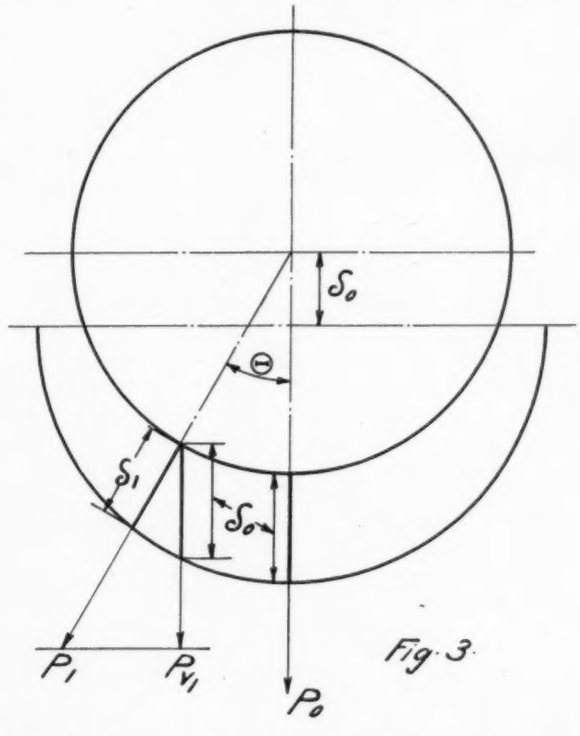

Fig. 3

is due of course to the much larger contact of area of the roller in compression. To what fraction of the ultimate strength the bearing can safely be loaded depends to a great extent upon a new factor to be considered, namely, wear, since once wear starts, the further useful life of the bearing is shortened, although the strength may yet be sufficient. Wear, obviously a function of the finish and hardness of the material (high grade alloy steel, hard-

ened throughout and ground, giving the best results) also depends upon the velocity at which the bearings operate and it is apparent that there exists a relationship between velocity and pressure for which wear does not take place to any extent. This relationship is best determined by test in determining the maximum stress, according to Hertz, for a number of cases and plotting same against velocity and measured wear. This determines the so-called speed factor, modifying the capacity of the bearing for various speed conditions.

It is thus perfectly safe to take the maximum allowable stress at about one-third of the ultimate strength (which at the same time is approximately the elastic limit of the material in compression) and to modify the capacity thus obtained by the speed factor. It should be remembered that the factor of safety of three, referring to the ultimate compressive stress, is considerably larger if referred to the ultimate crushing capacity of the bearing since, as was shown—the capacity is a function of the square of the stress. This means that the maximum allowable load would have to be increased nine times in order to increase the compressive stress three times.

There are, of course, a great number of other factors which render the interpretation of these tests rather difficult. Among these factors the influence of repeated shock loads on various materials is one of the most important. Nusbaumer (Paris) reports that no matter what description of repeated stresses a material be subjected to, it may, even when working below its elastic limit, break, if the stress is repeated a sufficient number of times. It remains to be ascertained whether fracture always occurs or whether there is a certain limiting amount of stress at which resistance may be displayed practically indefinitely. This, of course, is true in general and is merely mentioned here to show the complexity of problems involved.

Due to the bending on the rolls, the pressure distribution over the bearing length is obviously not uniform and this has to be considered in the design. Compensation for this condition is best accomplished by a ball and socket type housing. The not uniform distribution would then be eliminated after overcoming the frictional resistance of the aligning seat. This is considered the best solution, because with it the maximum contact area between rollers and races can be maintained, while all designs to incorporate this feature directly in the roller assembly are possible only by making some concessions, usually affecting the contact area, thus reducing the capacity of the bearing, which, while satisfactory for light service conditions is not quite quite so satisfactory for rolling mill requirements.

The application of roller bearings to cluster and 4-high mills does not present any serious difficulties, since, due to the arrangement of the backing-up rolls, the bearings can be made as large in outside diameter as desired. At the same time, load conditions are more favorable since the rolls are backed up the total length, reducing bending and deflection. Mills of this type are already equipped with roller bearings of various types. However, it is the commercial 2-high and also 3-high mills which have the greatest limitations, the load conditions being at the same time very high. For these mills, due to their limitations, the possibility of application of anti-friction bearings has been regarded as impractical, if not impossible. The cylindrical roller bearing, however, will successfully meet the limitations as well as load conditions of this type of mill, because the whole capacity of the bearing is used to carry the heavy radial loads, no compromise being made to take care of thrust loads which are really of secondary importance and which can easily be provided for by the use of separate thrust bearings.

Such thrust bearings only slightly increase the overall length of the bearing assembly and the initial cost of the complete bearing.

The Rollway Bearing Company has developed a series of bearings for the most common sizes of these commercial 2-high mills for cold as well as hot rolling. Some of these bearings are in actual construction and will be put in operation before long.

If this paper succeeds in showing upon what principles the design of these bearings are based, it will have accomplished its purpose.

Pertinent Facts About
Iron and Steel Exposition
Syria Mosque Pittsburgh, Pa.

The opening and closing hours of the Exposition are:

Monday—1:00 P. M. to 10:00 P. M.
Tuesday—1:00 P. M. to 10:00 P. M.
Wednesday—1:00 P. M. to 5:00 P. M.
Thursday—10 to 12 Noon and 7 to 10 P. M.
Friday—1:00 P. M. to 10:00 P. M.
Saturday—1:00 P. M. to 10:00 P. M.

Admission to the exposition is by card only.

On Monday evening at the Pittsburgh Athletic Association Annex, the Annual Informal Reception and Dance will take place, beginning at 9:00 P. M. W. E. Miller, Elec. Supt., Bethlehem Steel Company, Johnstown, Pa., is Chairman.

You are invited to be present as the guest of the Association of Iron and Steel Electrical Engineers.

At 7:00 P. M. Wednesday evening, the Association will hold its Annual Dinner Dance. So as to avoid any confusion, you are requested to secure your tickets on Monday morning, June 13th, at the registration headquarters or from the committee in charge of the Dance. Mr. A. G. Place, Elec. Engr., Youngstown Sheet & Tube Company, Youngstown, Ohio, is Chairman.

On Thursday afternoon, those in attendance at the Iron and Steel Exposition and Convention are invited to inspect the New Structural Mills of the Homestead Steel Works, Carnegie Steel Company, Munhall, Pa. Special cars will take the guests to and from the plant. The final details may be had by consulting the bulletin board and by attendance at the technical session on Thursday morning.

As only a limited number of the June Issues of Iron and Steel Engineer was printed, you are requested to take this copy with you to the convention and exposition and keep it in your possession throughout the week.

*Electrical Installations New Structural Mills, Homestead Steel Works, Carnegie Steel Co., Munhall, Pa.**

By C. A. MENK†

THE Homestead Steel Works is located in the Monongahela River Valley about ten miles from Pittsburgh. It is made up of a blast furnace plant with seven blast furnaces located on the north side of the river, and across the river are located sixty-five open hearth furnaces, two Universal Slabbing Mills, two Blooming Mills, five Sheared Plate Mills, two Universal Plate Mills, two Structural Finishing Mills, one Axle Making Plant and an Armor Plate Department.

The furnace plant is connected with the mills by means of a heavy bridge capable of sustaining the heavy trains of ore and molten metal conveyed over it. The Schoen Steel Wheel Works is also under the same management and is located at McKees Rocks about fifteen miles from the Steel Works.

The mills to be described in this paper, known as the New Structural Mills, consist of two groups of mills, No. 1 Group being made up of a 44″ Blooming Mill, a 36″ Roughing Mill and a 28/32″ Finishing Mill. These mills are designed to roll the standard structural shapes, channels, I-Beams, angles, etc. The finished product varies in size from 6″x4″ angle to 24″ I-Beam.

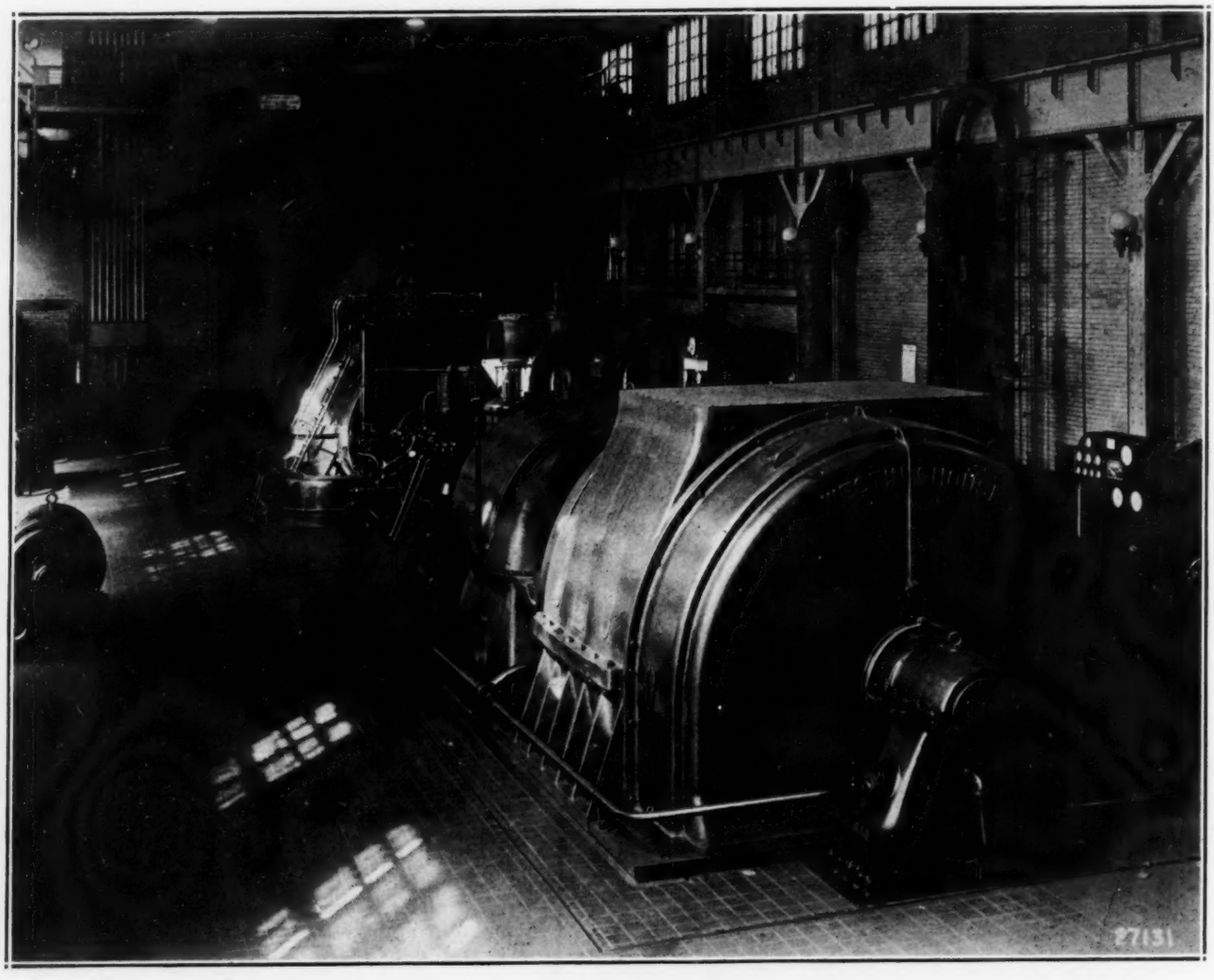

FIG. 1.

No. 2 Group consists of a 54″ Blooming Mill, and a 52″ Carnegie Beam Mill consisting of a 52″ Rougher, 52″ Intermediate and 52″ Finishing Stands.

These mills occupy the site of the old 28″ Blooming Mill, 38″ Blooming Mill, 40″ Cogging Mill, 33″ Cogging Mill, 35″ Structural Finishing Mill, 23″

*To be Presented at Annual Convention, June 13th to 18th, 1927, Pittsburgh, Pa.

†Electrical Superintendent, Homestead Steel Works, Carnegie Steel Co., Munhall, Pa.

Structural Finishing Mill and the 33" Structural Finishing Mill; and the product formerly rolled in these mills is now being made by No. 1 Group. No. 2 Group is engaged in the manufacture of the new Carnegie Beam exclusively. During periods when either No. 1 or No. 2 Finishing Mill is shut down for roll changes or other causes, the blooming mills are used

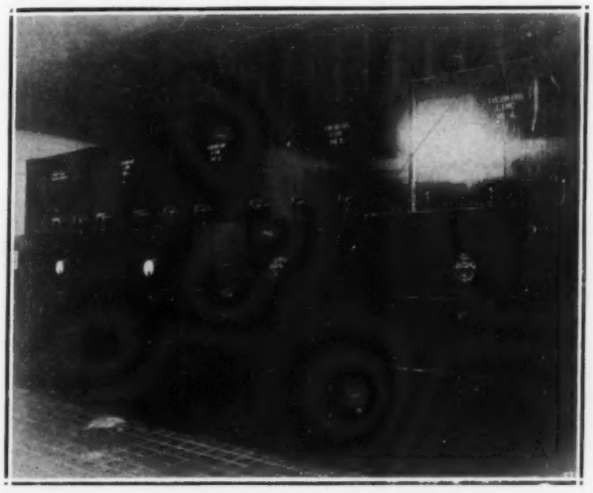

FIG. 2.

for rolling slabs for plate mills, axle blooms for Howard Axle Works and rounds for Schoen Steel Wheel Works.

None of the old mills in the Structural Department were of modern design and the operating costs of seven separate mills, six of which were supplied with steam from four boiler houses, were out of proportion to the tonnage which they could ever be expected to produce. To secure the economies obtained by consolidation of mills into a closely united group under one superintendent, and employment of the latest rolling methods and equipment for obtaining the increased production, it was necessary to replace the seven old mills with the new No. 1 Group. Electric drive was installed in all the new mills because of its inherent economy and the saving in operating labor obtained thereby.

It was necessary to install an additional 15,000 K.W. Turbo-Generator in the power house at Carrie Furnaces (Fig. 1) to supply the increased demand for power for these two new groups of mills. The units are supplied with steam from six waste gas fired boilers and six coal fired boilers. The coal fired boilers are used only when absolutely necessary. This brings the generating capacity at Carrie Furnaces up to 42,800 K.W. made up of the following units:

2—15,000 K.W.	Turbo-Generators	30,000 K.W.
3— 1,600 K.W.	Gas Engine Driven Generators	4,800 K.W.
2— 2,500 K.W.	Gas Engine Driven Generators	5,000 K.W.
1— 3,000 K.W.	Gas Engine Driven Generators	3,000 K.W.
Total		42,800 K.W.

A 3000 K.W. Low Pressure Turbo-Generator located in the Homestead Steel Works makes the total generating capacity of the system 45,800 K.W.

Power is transmitted from Carrie Furnaces Power House to the New Structural Mills over 4-3 Phase, 6600 volt, 25 cycle, circuits. The cable used is 500,000 C.M. hard drawn stranded copper except for the 1200 foot span over the Monongahela River and two long spans over the Mill Buildings at the Homestead Works where steel reinforced aluminum cable, equivalent of 500,000 C.M. copper is used. This transmission line is supported on steel towers throughout.

These circuits are fed into a bus through four truck type oil circuit breakers (Fig. 2) having a rupturing capacity at 6600 volts of 36,000 amperes, 2 O.C.O. duty cycle. This bus structure begins at the east end of the main motor house, extends through the basement to the west end, thence through a tunnel (Fig. 2A) to the basement under the 44" and 54" Blooming Mill Motors, a distance of 850 feet. Midway between the two motor rooms the tunnel enters the basement of the transformer sub-station, and at this point four oil circuit breakers, duplicate of those on the incoming lines, are located. These breakers are to be connected, eventually, to four other circuits when the Loop System is installed and will provide two sources of power transmission to the New Structural Mills. Lighting protection is afforded by outdoor type auto-valve lightning arresters and choke coils installed

FIG. 2A.

on the terminal tower which is located at the east end of the main motor house.

No. 1 Group of mills is served by twenty-eight soaking pits. The covers of these pits are motor-driven and are operated, during the charging and drawing of ingots, by the soaking pit craneman through control equipment. This control requires only a single wire

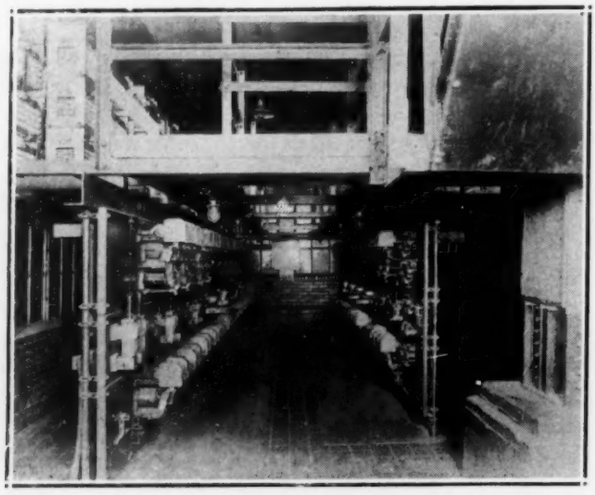

FIG. 3.

to open or close the cover which is stopped at the end of opening or closing stroke by means of a limit switch.

When the master controller is moved to the on position a directional relay energizes the forward switches and as long as the master controller is left in that position the cover will continue to open until it reaches the full open position when it is stopped by the limit switch and the dynamic braking control. The door will remain open until the master switch is brought to the off position when the directional relay is de-energized and the back contacts, established when the relay opens, energize the reverse contactors of the controller and the cover is closed. A limit switch stops the motor at the end of the stroke as was done in opening. With this scheme the craneman does not have to remain over the pit while the door is closing, which enables him to get away from the heat and to do other work when necessary.

The twenty-eight soaking pits are arranged in seven lines running north and south, four in each line, and the two 15-ton low stiff leg type soaking pit cranes whose girders run north and south, cover four soaking pits at one time. The lines of pits are located about 40 feet apart and the contact rails are sectionalized every 40 feet to correspond. There are four contact rails in each section, one for each cover, and four master controllers in each crane. Either crane can therefore open any cover when located over same.

Floor masters are provided to enable the heater to operate the covers when he is making bottom, etc., and he is able to stop the cover in any desired position.

After the hot ingots are drawn they are placed in an ingot car which runs lengthwise of the pits.

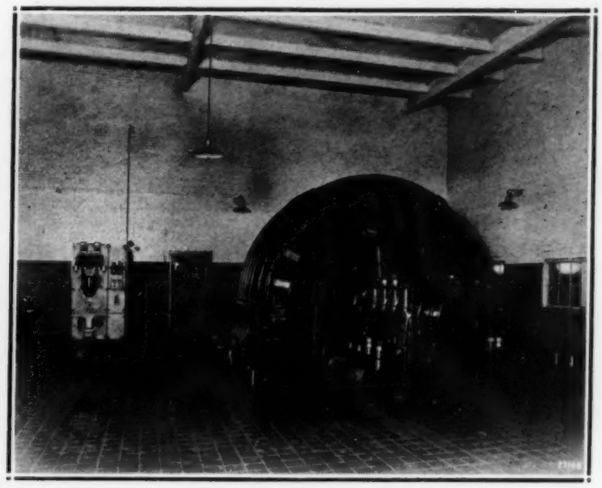

FIG. 4.

This ingot car is under the control of either cranemen and is spotted in the most convenient position beneath the crane for loading. When the ingot has been loaded in the car by the craneman he starts the loaded car toward the blooming mill, it being automatically slowed down and the ingot dumped on the waiting

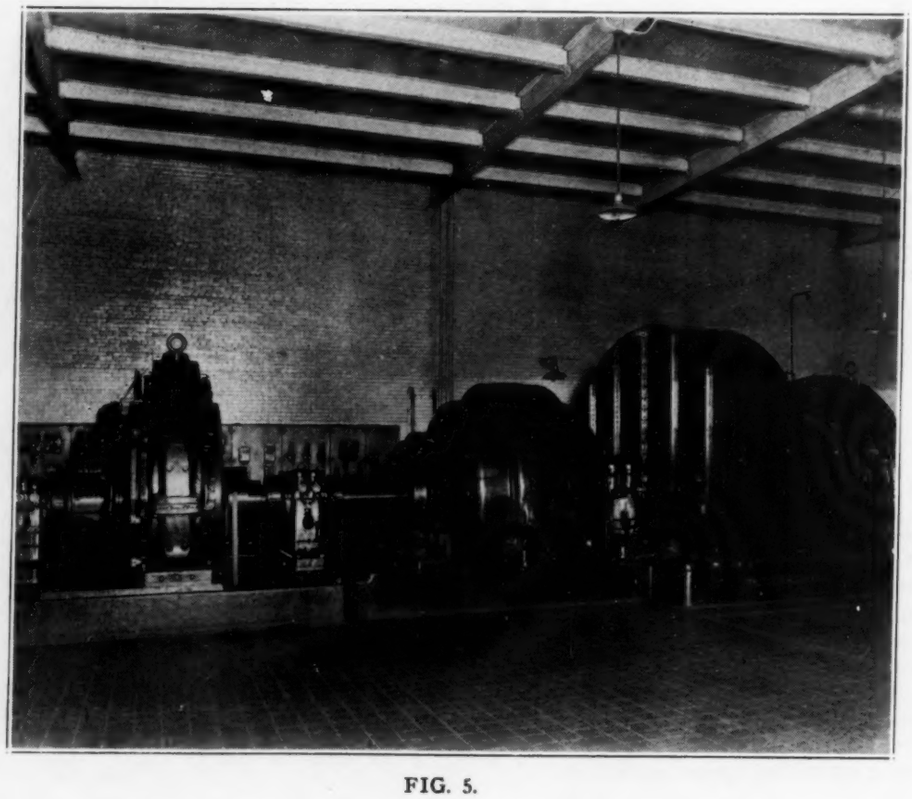

FIG. 5.

transfer car without any further attention from the craneman. The transfer car operates on a track running at right angles to the blooming mill tables and conveys the hot ingot from the ingot car to the approach table of the blooming mill.

The blooming mill serving the No. 1 Group has 44" diameter pinions and is of extra heavy construction to permit heavy drafting on the large ingots, ranging in weight from 8100 lbs. to 24,000 lbs. rolled in this mill. In order to meet the present-day demand for quick deliveries frequent roll changes are necessary. In order to meet this condition with the minimum loss of time an electrically operated quick roll changing device forms a part of the auxiliary equipment. The screw-down is equipped with two series wound mill type motors with magnetic brakes. These motors are connected in series both in raising and lowering the rolls. All mill auxiliary motors are supplied with washed air under pressure through a system of piping connected to a ventilating fan. These motors are equipped with suitable inlet and outlet ports. The auxiliary control for these motors (Fig. 3) is located in a room adjacent to the main motor house where it is easily kept clean and so arranged as to permit of easy inspection.

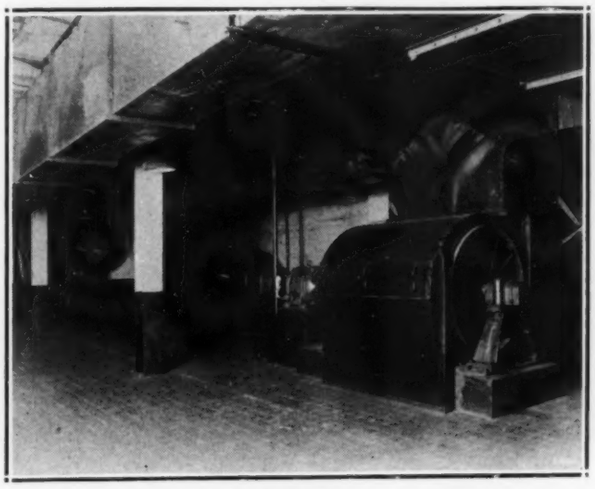

FIG. 6.

The main rolls are driven by a single unit reversing motor (Fig. 4) having a continuous rating of 7000 H.P. at 50 R.P.M. and a maximum torque of 2,000,000 pounds feet. This motor is supplied with variable voltage direct current through a flywheel motor generator set (Fig. 5) consisting of a 5000 H.P., 6600 volt, 3 phase, 25 cycle induction motor, a 100,000 lb. flywheel and two 3000 K.W., 700 volt, 368 R.P.M. generators operating in parallel. The ventilating equipment for the reversing motor consists of a 60,000 C.F.M. fan with air washer. All station auxiliaries such as ventilating fans, (Fig. 6) exciters and oil pumps are driven by 220 volt induction motors fed from a stepdown transformer bank located in the basement of the station.

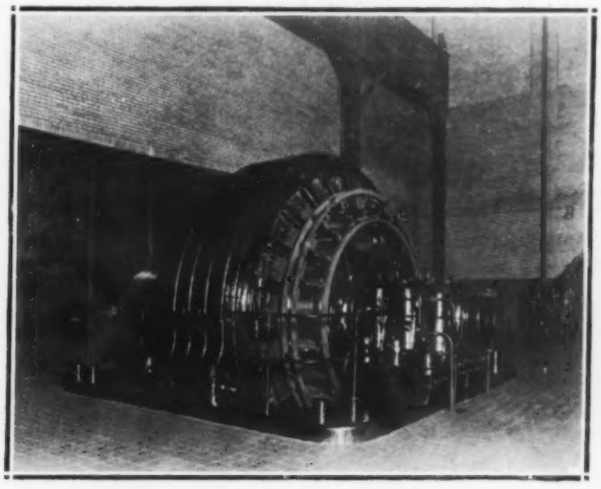

FIG. 8.

The mill being completely electrified, it is operated by two men in the mill pulpit (Fig. 7). The roller controls the setting of the rolls and operates front and back mill tables by means of hand master switches; and, by means of a foot master switch completely

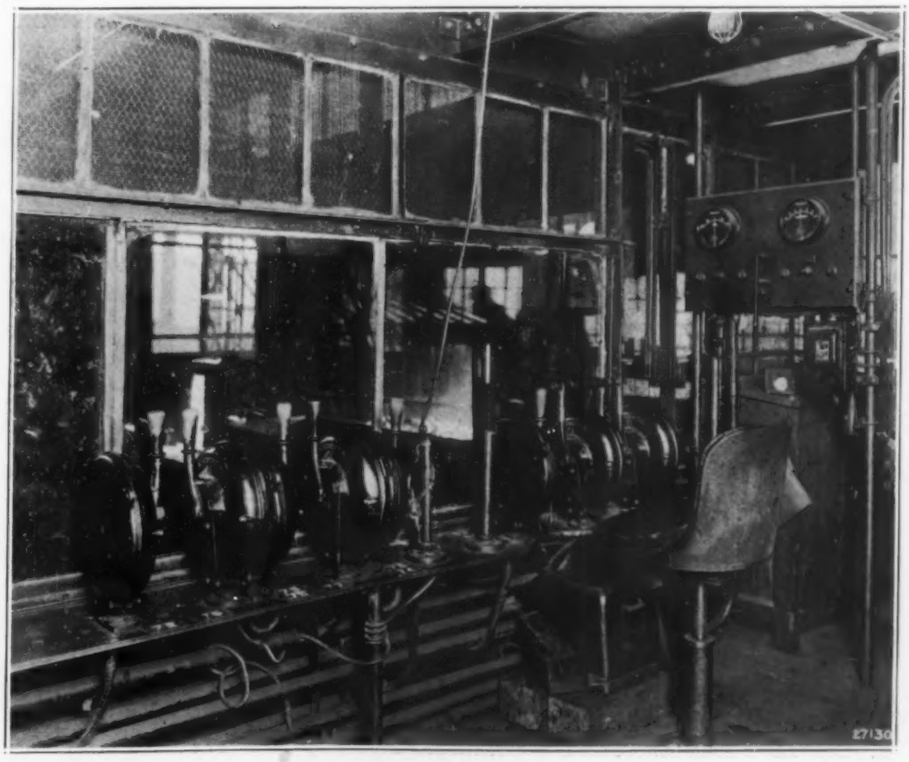

FIG. 7.

controls the speed and direction of rotation of the 7000 H.P. reversing motor. The duties of the roller's helper consists of the operation of the approach table, which brings the ingot to the mill, the runout table, which conveys the finished bloom to the shears and, during the rolling of the ingot the operation of the electrically driven manipulators.

The blooms are cut to the desired lengths by means of an electrically driven shear. This shear is equipped with one 250 H.P., 220 volt wound rotor induction motor for the main drive and a small motor for operating the clutch. There is an electrically operated gauge in connection with this shear. This gauge has two motors, one of which operates the gauge screw while the other operates the gauge stop. An ingenious crop end disposal mechanism forms a part of the auxiliary equipment of this shear and consists of a chain conveyer which transfers the crop-end to a tilting chute which dumps the scrap ends into a dump box on a narrow gauge car. These cars are spotted by the shear table operator by means of a small electrically driven, remote controlled locomotive.

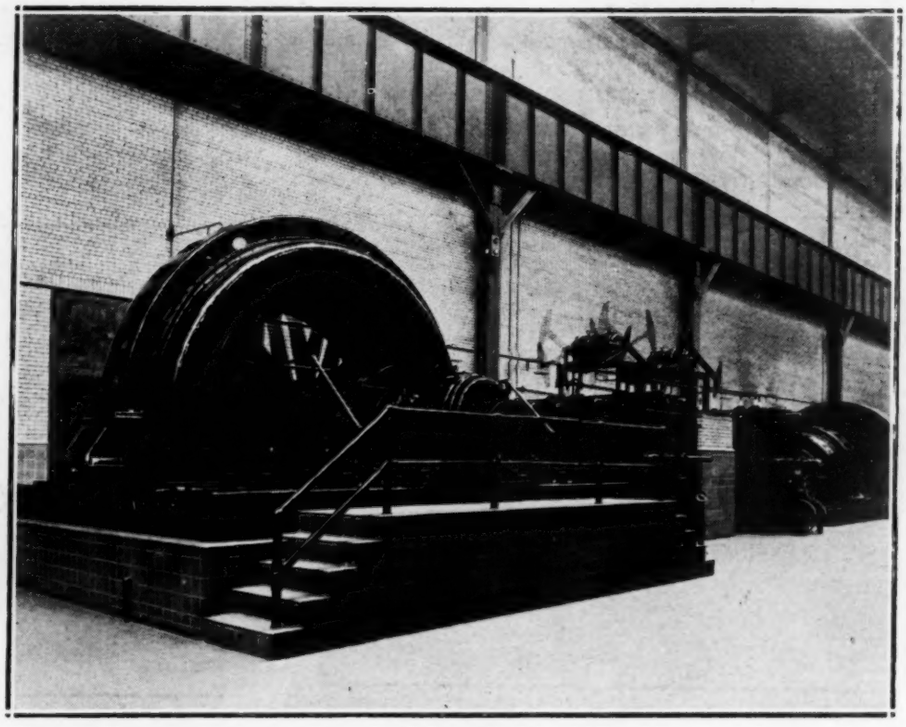

FIG. 10.

After the steel has been cut to the desired length it is conveyed by tables to a point from which it can be loaded into cars for shipment to other departments or transferred to the structural mill reheating furnaces by means of two 8-ton overhead revolving side grip charging machines. The charging machine operators in addition to operating the chargers themselves also operate the electrically driven doors of the reheating furnaces by means of remote control similar to that described for the soaking pit covers, thereby eliminating all furnace attendants except the heater. A secondary controller located on the floor permits the heater to raise or lower the doors when necessary.

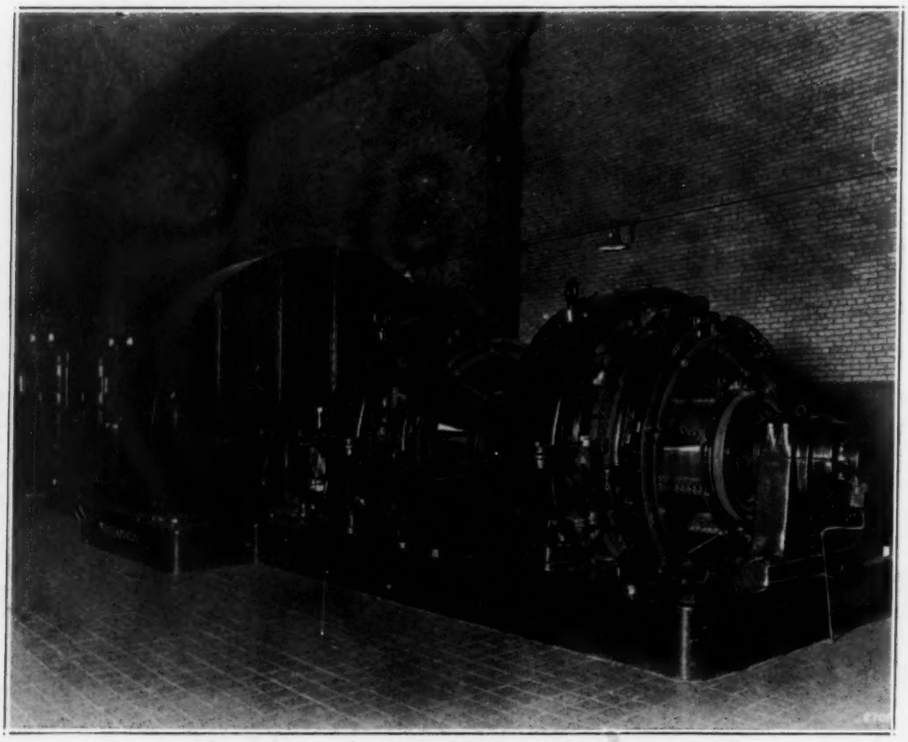

FIG. 9.

The same charging machines deliver the reheated blooms to the 36" Mill where they are given the desired number of roughing passes. This mill is of the 2-high reversing type and is driven by a 5000 H.P. direct current reversing motor (Fig. 8). The flywheel motor generator set (Fig. 9) for this motor consists of a 5000 H.P. induction motor, a 100,000 lb. flywheel and two 2100 K.W. 700 volt, 368 R.P.M. generators operating in parallel. The

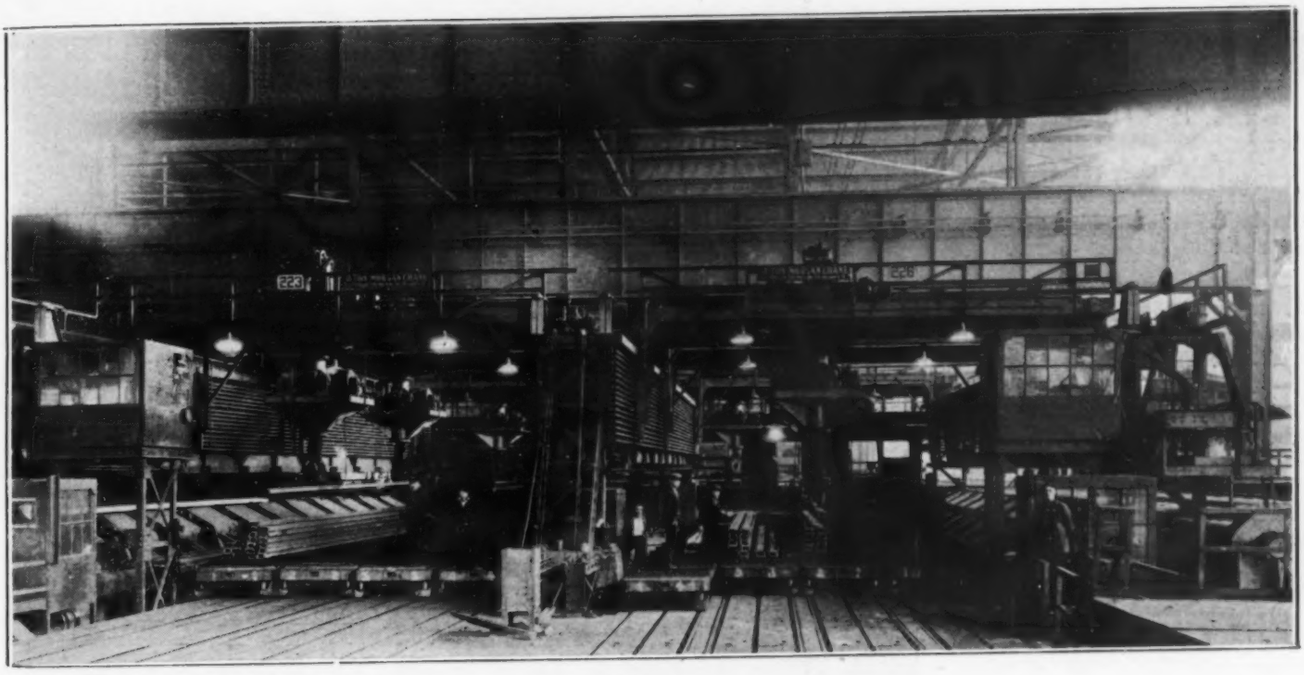

FIG. 11.

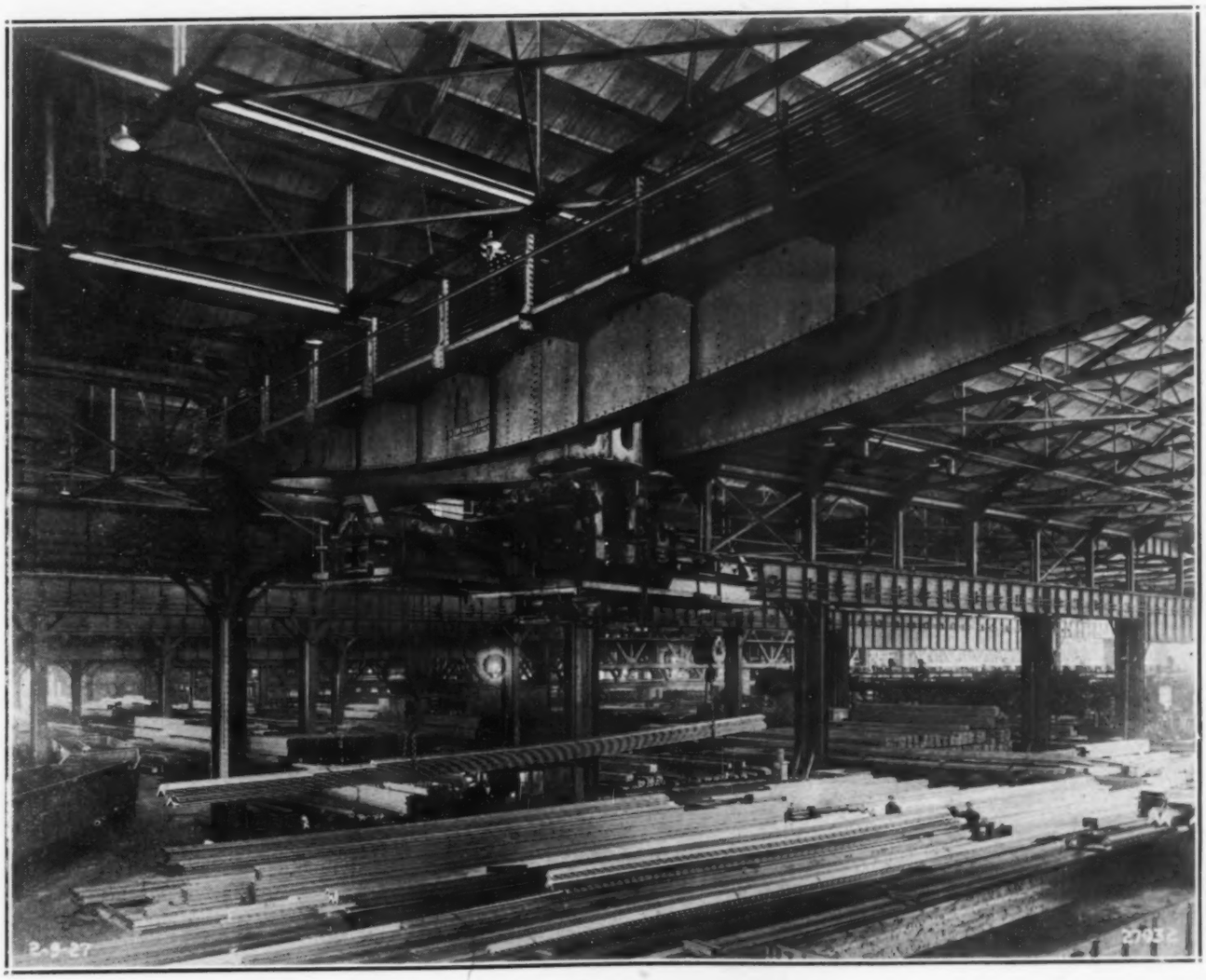

FIG. 12.

equipment was originally purchased with a smaller driving motor for the flywheel set, but was later changed to 5000 H.P., thus making the driving motors of five flywheel sets interchangeable. This mill has the same number of pulpit operators as the 44" Blooming Mill and they have corresponding duties.

After the bloom has been reduced to the desired cross section in the 36" Roughing Mill it is delivered to traveling tilting tables, serving the 28/32", 3-high, 4-stand Structural Mill, where it is given the scheduled number of passes and finished. This mill is driven by a 6000 H.P., 30 pole, 98 R.P.M., 6600 volt, 3 phase, 25 cycle wound rotor induction motor (Fig. 10). Between the mill pinion housing and the motor there is a 75-ton, 27'-6" diameter cast steel flywheel supported by pedestal bearings similar to those used on the reversing motors. A universal coupling forms the connection between the flywheel shaft and the 6000 H.P. induction motor.

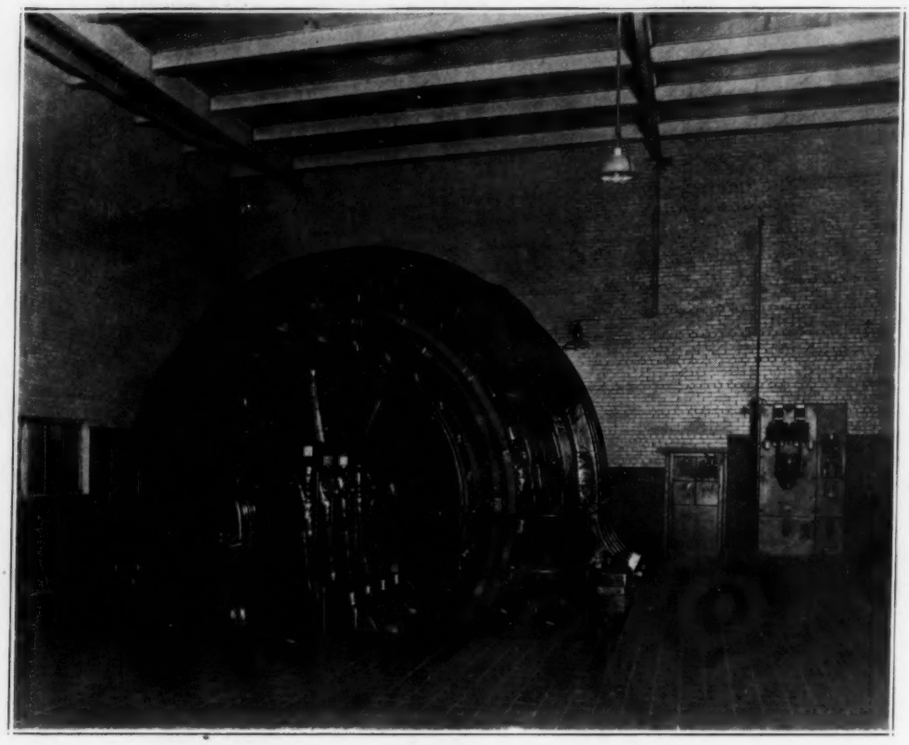

FIG. 13.

The 28/32" Mill, known as No. 1 Finishing Mill, is run by four operators located on two stationary pulpits spanning the four traveling tables, two on each side of the mill. Push buttons located in the mill pulpit provide for emergency stopping and starting of the 6000 H.P. motor.

The finished product leaving the 28/32" Mill is cut into desired lengths by a motor-driven hot saw which

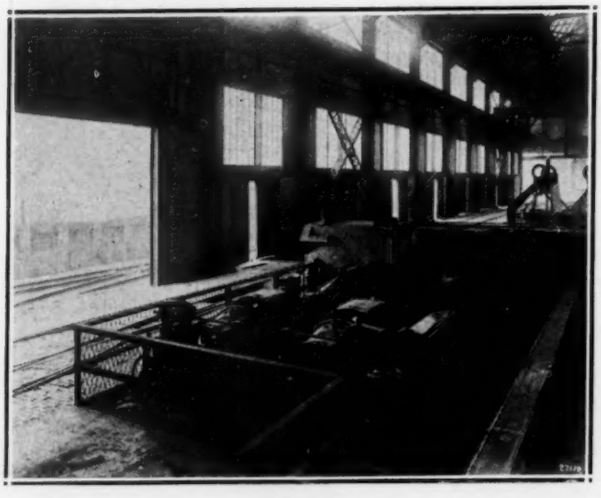

FIG. 14.

is equipped with a 250 H.P. wound rotor induction motor, and is then delivered to the cooling beds. After it has cooled to the desired temperature it is passed through the variable speed motor driven straightening rolls and goes to the inspection bed. Special equipment is installed to turn over the product to permit of easy inspection. The product after being thoroughly inspected is cut into desired lengths for shipping by two electrically-driven shears each requiring a 125 H.P. wound rotor induction motor. The scrap drops into a pit from which it is loaded into cars by means of a crane equipped with a lifting magnet. The sheared product then goes to the Shipping Department where it is separated and piled for the various customers.

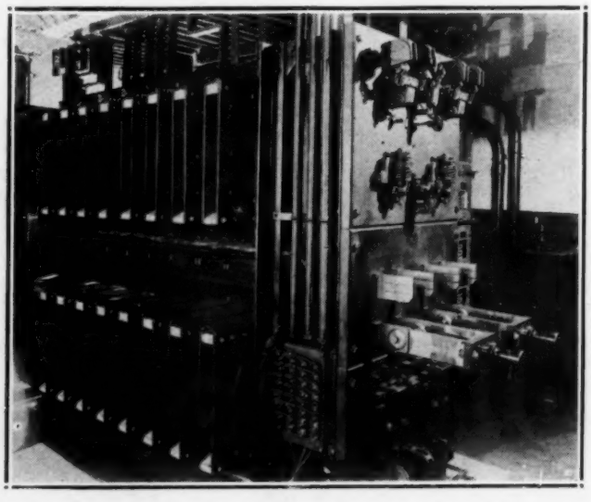

FIG. 15.

Six specially designed magnet piling cranes (Fig. 11) are used for this work, making possible the performance of this otherwise difficult and dangerous task in a very safe and efficient manner with the least possible number of men.

Material which cannot be sheared is cut into de-

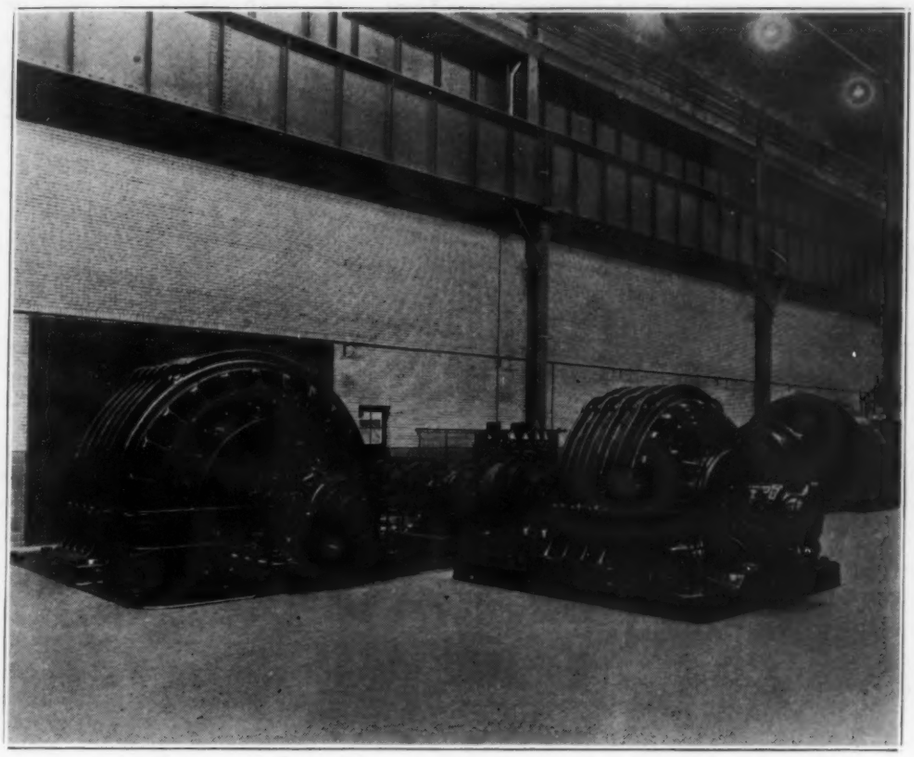

FIG. 16.

sired lengths by a motor-driven cold saw which is equipped with a 250 H.P., 220 volts wound rotor induction motor.

The product reaches the loading yard at right angles to the tracks. The difficulty of loading under these conditions is overcome by the use of three loading cranes (Fig. 12), each being equipped with two hoists suspended from a revolving table. The crane operator is thus enabled to place the loads in any desired position. To adjust for varying lengths of material the two 10-ton independently driven hoists are separated or drawn close together by means of a right and left hand screw which keeps the two hoists equi-distant from the center of the trolley. With this type of crane no lifting beam is required. All yard cranes are equipped with two 10-ton trolleys to facilitate handling long material without resorting to the use of a lifting beam.

Paralleling the No. 1 Group of mills described above is the No. 2 Group, the first unit of which is the 54" Blooming Mill. This mill, like the 44" Mill, is served by twenty-eight soaking pits covered by two 15-ton low stiff leg type soaking pit cranes. The soaking pit covers, ingot car and transfer car are operated as explained under the 44" Mill. One man operates the two transfer cars serving the 44" and 54" Mills. He also controls both ingot cars in the dumping zone.

The hot ingots, ranging in weight from 12,000 lbs. to 30,000 lbs., are delivered to the 54" Mill where they are rolled into blooms of proper cross section to roll into Carnegie Beams, slabs for the plate mills, or rounds for the Schoen Steel Wheel Works. This mill is similar in construction to the 44" Mill, but proportionately larger and is the largest blooming mill ever built. It is driven by the largest reversing motor in the world (Fig. 13) which has a continuous rating of 8000 H.P. at 40 R.P.M. and a maximum torque of 3½ million pounds feet. The flywheel set consists of a 5000 H.P. driving motor, a 150,000 lb. flywheel and two 3500 K.W., 700 volt, 368 R.P.M. generators operating in parallel. The motor is supplied with 60,000 cubic feet of washed air per minute through a ventilating system similar to that which supplies the 44" Mill.

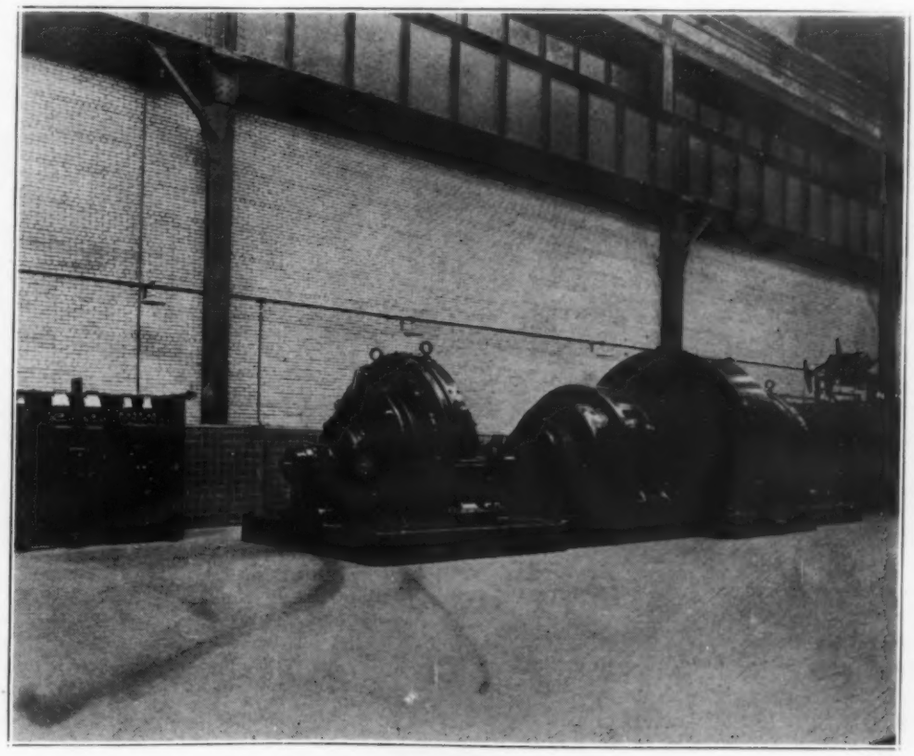

FIG. 17.

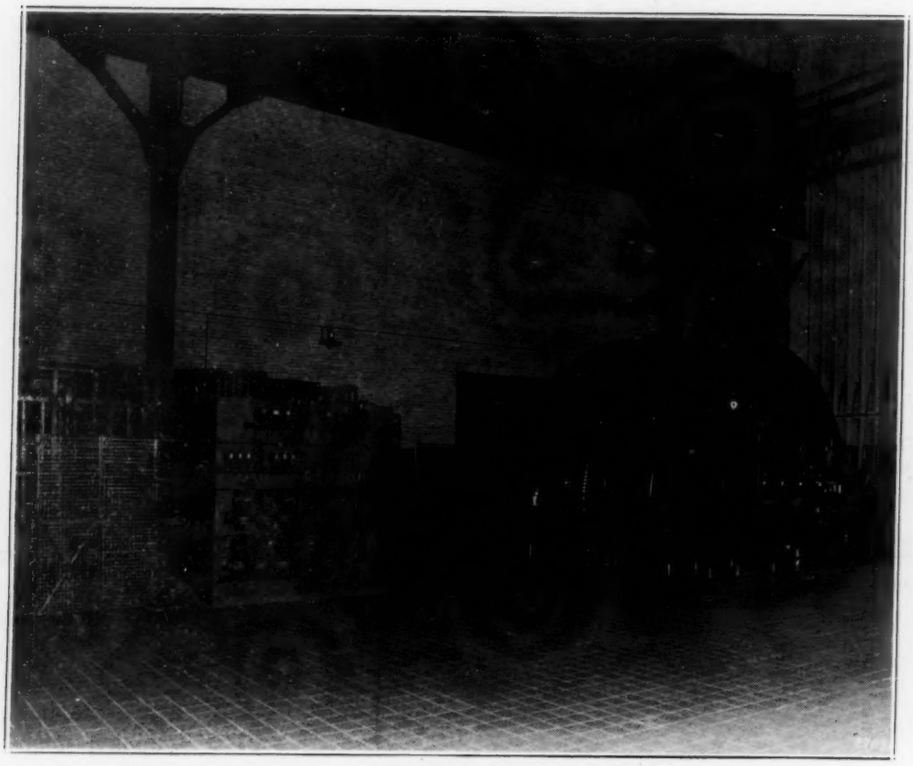

FIG. 18.

Two operators control the main and auxiliary drives in this mill in the same manner as the 44″ Mill. When the mill is rolling rounds for the Schoen Steel Wheel Plant, the circular bloom has the crop end cut off in the bloom shear. It is then conveyed by means of a transfer and swinging table to another group of tables at an angle of approximately 30° to the line of the mill where it is taken to a specially designed shear for cutting the round bloom into suitable lengths for wheel blanks. When slabs are rolled in this mill they are also conveyed on the swinging table to a location where they are piled and loaded on narrow gauge buggies for shipment to the plate mills.

The shear for cutting the circular bloom into desired lengths for wheel blanks is driven by two 275 H.P., 1 hour rating, mill type motors (Fig. 14). These motors are connected by gearing to two racks to which are attached the cutting blades. These blades are in the same vertical plane and travel horizontally. The cutting edges are parallel to each other and at an angle of approximately 15° to 20° with the horizontal. When the cutting blades are separated the circular bloom passes between the blades until it engages a stop which determines the length of the wheel blank to be cut. The cutting blades are then made to approach each other causing the circular bloom to revolve as the cutting takes place. When the wheel blank has been severed the knives are stopped and reversed by the automatic electro-pnematic control (Fig. 15). Chutes convey the wheel blanks and the scrap ends to separate buckets. The operator separates the good material from the scrap by means of motor operated gates. The loaded buckets are removed from the pit under the chute by a 15-ton E.O.T. crane.

When Carnegie Beams are being rolled the hot bloom from the 54° Mill is conveyed directly to the Finishing Mills. The bloom then enters the 52″ Roughing Mill, where it is given the scheduled number of passes. It is then conveyed by means of tables and transfers directly to the 52″ Intermediate Mill where it is reduced in cross section to almost the finished size. From the Intermediate Mill the beam goes directly to the Finishing Mill where it is given the finishing pass. The finished beam is then sawed into

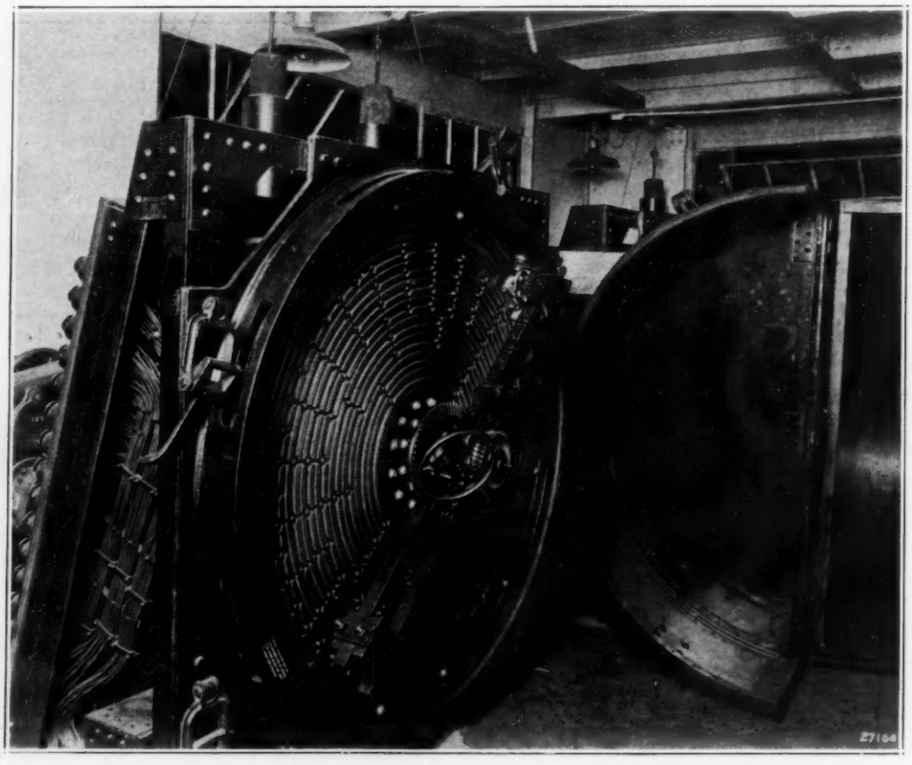

FIG. 19.

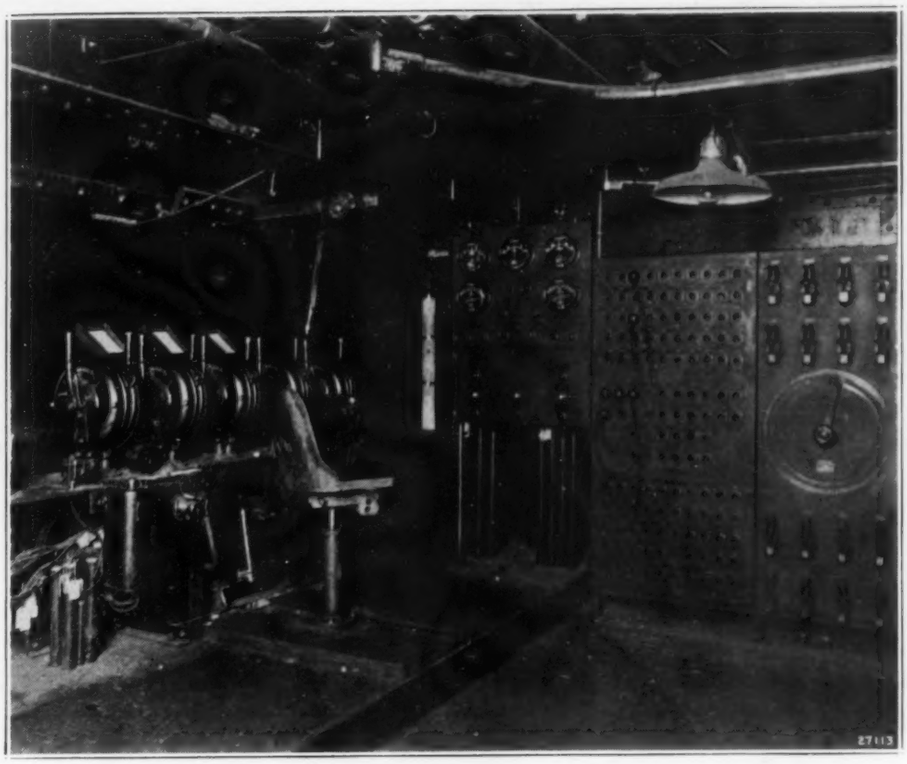

FIG. 20.

proper lengths and taken to the cooling beds. After the beams leave the cooling bed they are inspected, straightened, if necessary, sawed into the lengths specified for shipment or sent to the spacious storage yards where a sufficient stock of the new Carnegie beams is stored to meet the trade demands.

The Roughing and Intermediate Mills are exact duplicates, each mill consisting of an edging stand operating in tandem with the main stand which has both horizontal and vertical rolls. Each stand is driven by a separate reversing motor (Fig. 16). The edging stand is driven by a 2000 H.P., 57/163 R.P.M. reversing motor and the main stand is driven by a 7000 H.P., 50/80 R.P.M. reversing motor. Both motors receive D.C. power from a 6000 K.W. 700 volt flywheel motor generator set (Fig. 17). The finishing stand is driven by a 4000 H.P., 6600 volt, 3 phase, 25 cycle, 83 R.P.M. wound rotor induction motor (Fig. 18). This motor with its control was taken from the old 33″ Structural Mill after that mill was dismantled.

The Roughing and Intermediate Mills are each equipped with an automatic screwdown device which enables one man using a single master switch to set the three screwdowns which automatically stop at predetermined settings by means of a specially designed limit switch (Fig. 19) and secure the proper speed relations between the motors driving the main and edging stands for any condition of drafting. A standard foot master switch enables him to control the speed and direction of rotation of both mill motors. Owing to the ease with which one man can set the screwdowns and control the main motors, he is also able to run the approach table, the front and back tables and to operate the valves controlling the cooling water for the rolls and the steam jets for removing scale. This man controls thirteen operations during the rolling of each beam. Since the drafting follows a predetermined schedule and the roll settings are made automatically a uniform product free from internal rolling stresses caused by irregular drafting, is obtained. Fig. 20 shows the operator's pulpit for the 52″ Roughing Mill, while Fig. 21 shows the magnetic control used in connection with the automatic limit switch and forms part of the screwdown equipment.

The Finishing Mill is 2-high and has both horizontal and vertical rolls. This is a fixed pass mill, is non-reversing and makes but one pass.

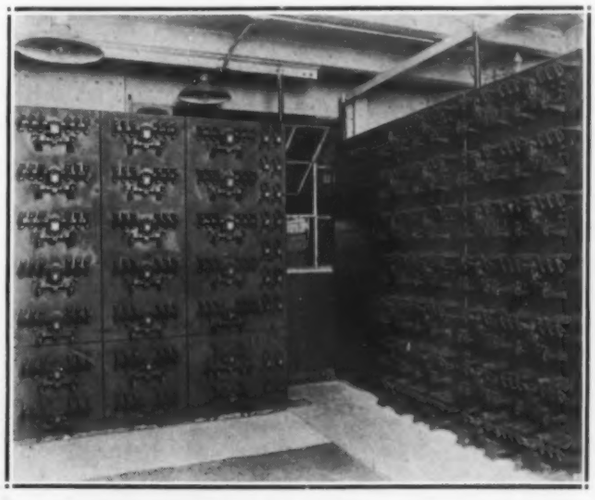

FIG. 21.

From the time the bloom leaves the bloom shear until the finished beam is delivered from the finishing pass all operations are controlled by three men.

Two 1500 K.W. Synchronous Motor Generator Sets (Fig. 22) supply the necessary 230 volt Direct

Current for the mill auxiliaries. Provision has been made on the switchboard and foundation provided, for a third motor generator set which is to be installed. An automatic switchboard (Fig. 23) forms part of this equipment and provides complete protection without any attendants. These sets are started from rest by the operator throwing a starting switch. They are brought up to speed, synchronized and connected to the D.C. bus automatically. The load of the two machines is also balanced automatically. All feeder circuits are equipped with circuit breakers which open only on short circuit. Special provision is made to prevent damage to the Motor Generators through overload.

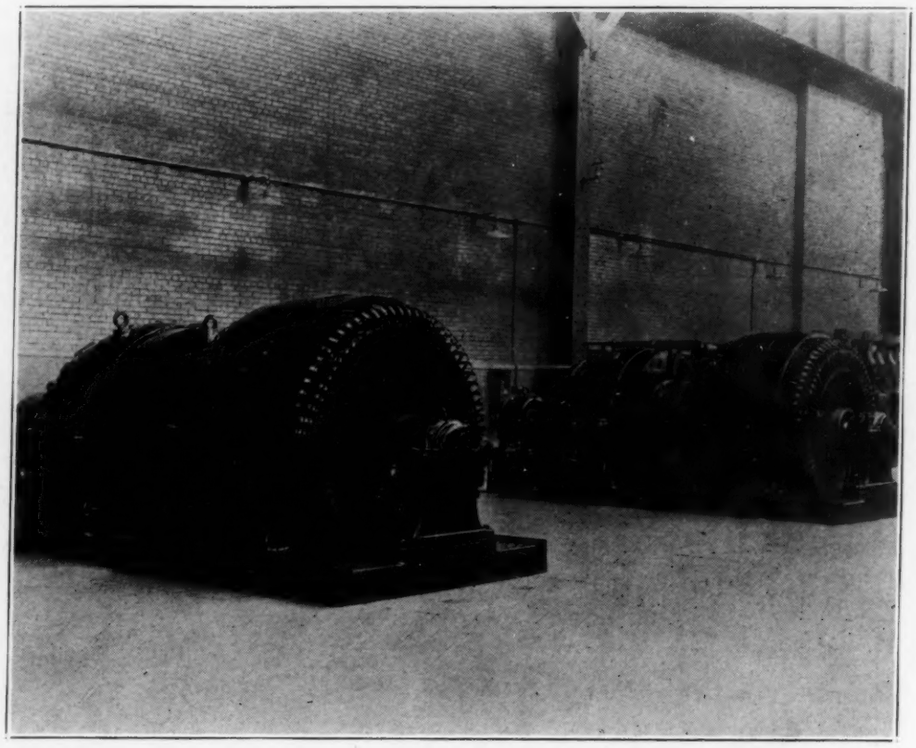

FIG. 22.

Fig. 24 shows a general view of the room which contains all the main motors for the Finishing Mills as well as the automatic sub-station. The combined continuous rating of the main drive mill motors, located in this room, is 34,000 H.P. In addition to the two 1500 K.W. Motor Generator Sets supplying the D.C. current to the auxiliary motors, are three flywheel Motor Generator Sets which supply the D.C. power to the main drive reversing mill motors. Their total generating capacity is 16,200 K.W., the driving motors totaling 15,000 H.P. The motor house is served by an 80-ton crane with a 15-ton Auxiliary Hoist.

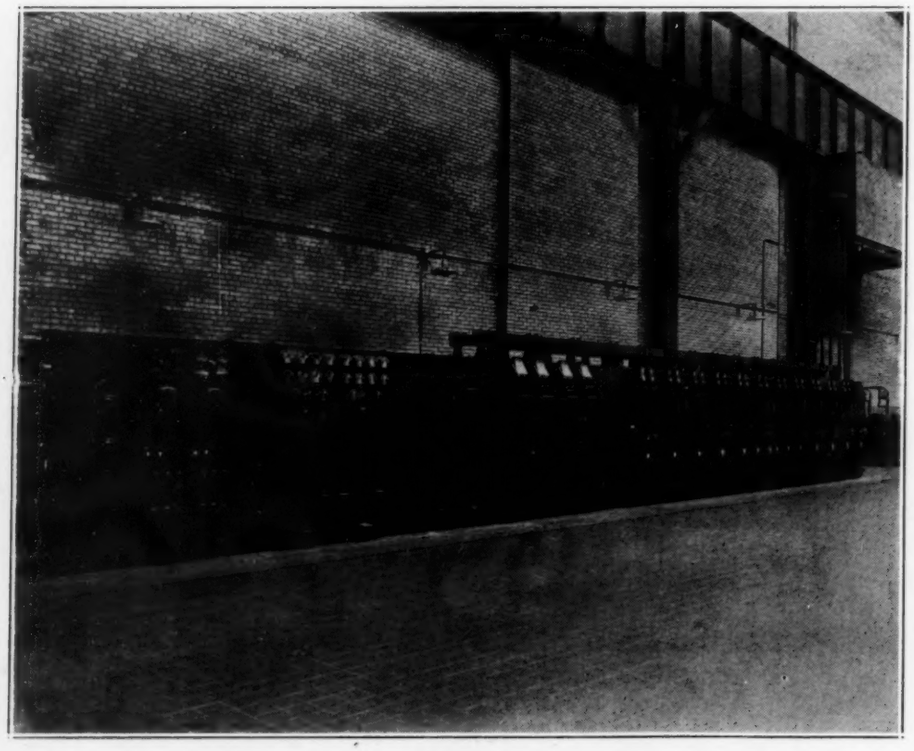

FIG. 23.

The switchboard for the main mill motors is shown on Fig. 25. Fig. 26 shows the test bench by means of which a complete test can be made of any of the main motors. A variable speed motor drives a line shaft to which is belted all of the recording instruments. All charts therefore have the same time base. The same instruments are used for the five reversing motors. Transfer switches mounted on the front of the board make it convenient to connect up with the desired motor. The clock pendelum marks all charts simultaneously.

Most of the auxiliary mill motor control equipment is installed in the thir-

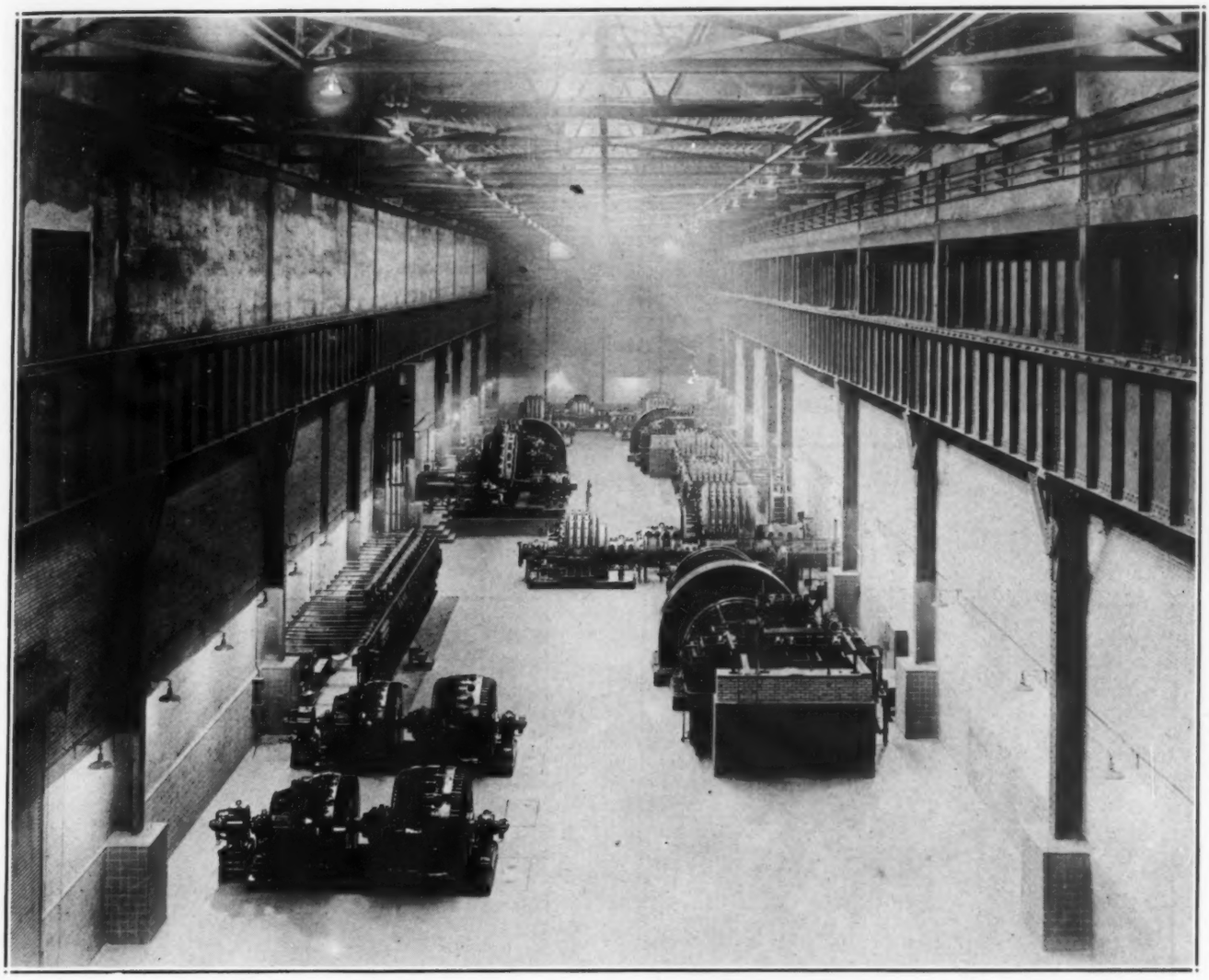

FIG. 24

teen underground control rooms. This permits of locating the controls close to motors without occupying room above ground which often is not available for this use. The isolating of this equipment, where workmen cannot come in contact with same and accessibility afforded the electrical repairman makes this type of installation very desirable, and provides the maximum of safety. Fig. 27 shows a typical installation. All master switches, motors and controllers are marked for identification.

Sixty-one cranes serve both groups of mills and yards. These cranes vary in capacity from five to two hundred seventy-five tons and cover practically every square foot of the 26½ acres under roof. Fifty-four of these cranes are covered by traveling repair trolleys having sufficient capacity to lift the heaviest part of the crane to be served. This enables the small repair crew to make major repairs without the assistance of a rigging gang. The seven cranes not served by repair trolleys are of small capacity, and are equipped with an overhead beam to which the required lifting tackle can be easily attached.

Hydraulic pressure for the New Structural Mills is obtained from four horizontal, duplex, double acting pumps (Fig. 28) designed for a pressure of 600 lbs. per square inch. Each pump has a capacity of 735 gal. per minute. The pumps are driven by 400 H.P., 220 volt, 3 phase, 25 cycle, synchronous motors equipped with magnetic control for automatic starting. A 26"x20'-0" accumulator forms a part of the hydraulic system.

Two air compressors each having a delivery of 1200 C.F.M. at 110 lbs. pressure, supply the required compressed air for the new mills, and are driven by 250 H.P., 220 volt, 3 phase, 25 cycle synchronous motors.

Three 1500 K.W. single phase, 25 cycle, 6600/220 Transformers (Fig. 29) supply all the power used by the low voltage A.C. motors. Another transformer, lo-

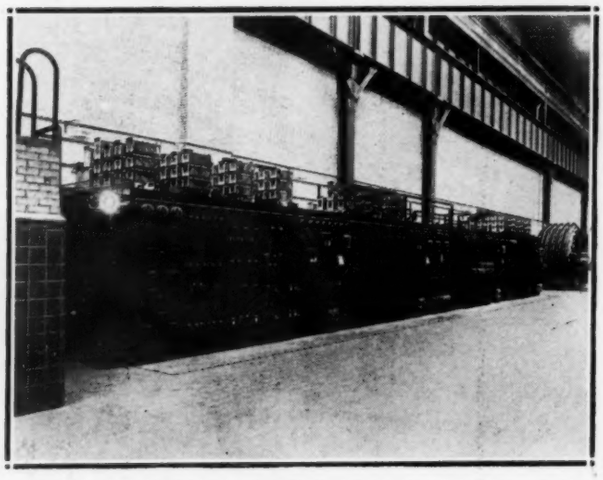

FIG. 25.

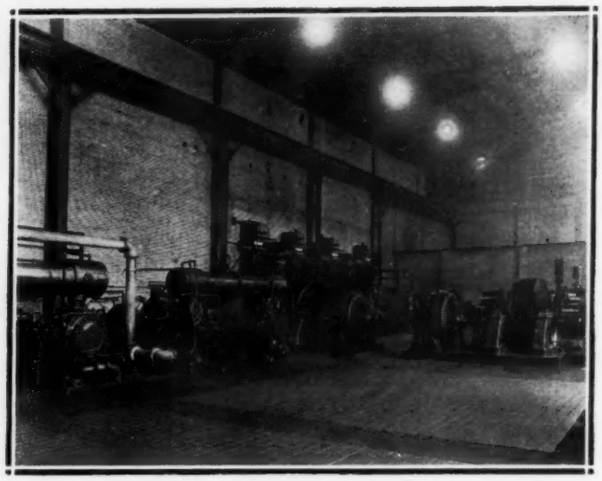

FIG. 28

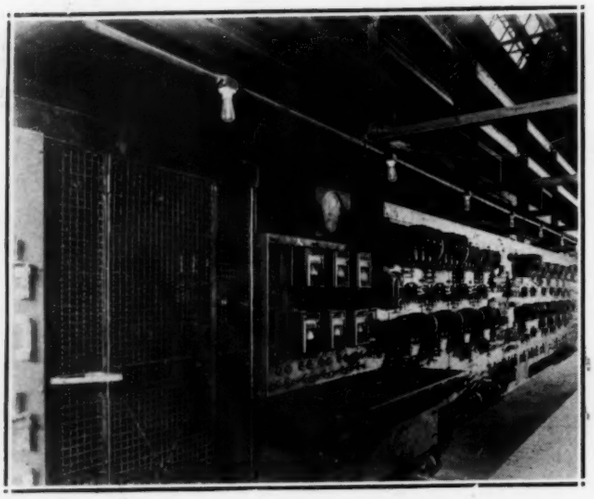

FIG. 26.

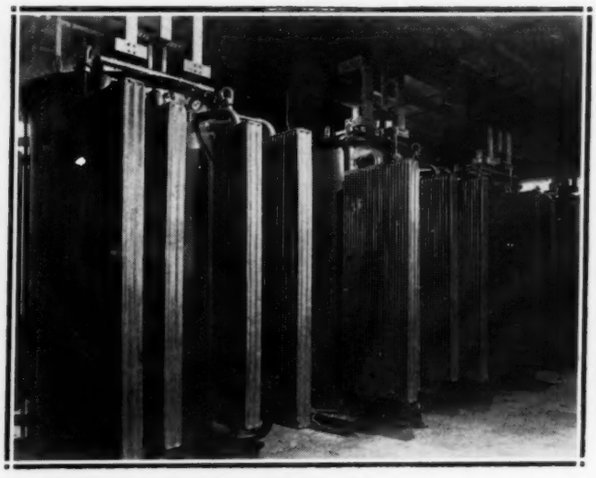

FIG. 29.

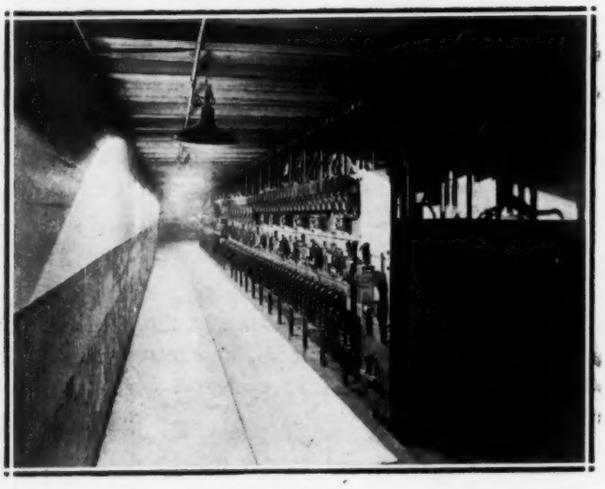

FIG. 27.

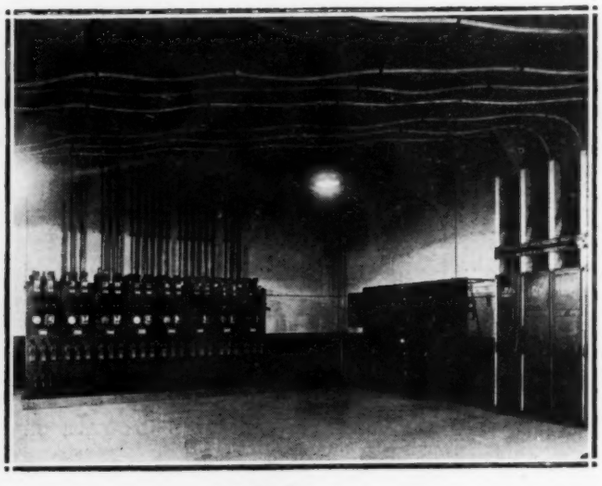

FIG. 30.

cated in the same room, supplies the power for lighting. Fig. 30 shows the 220 volts A.C. distribution panels for motors and the 110 volt A.C. panels for lighting. A few items of interest are given below:

Total area occupied	30 Acres
Area under roof	26½ Acres
Total length of crane runways	11,530 Feet
Total number of motors	836
Horsepower Auxiliary motors	50,935 H.P.
Horsepower Main Drive motors	49,000 H.P.
Horsepower of motors and generators used with main drive reversing motors	65,000 H.P.
TOTAL H. P.	164,935

Total length roller table	6,374 ft.
Total cubic yards excavation	307,390 ft.
Total cubic yards concrete poured	106,390 ft.
Car loads of material for new mill	10,773
Total weight of steel in new building erected not incluuding sheeting	53,637,000 lbs.
Number of tracings furnished by Homestead Steel Works Engineering Department	4,222
Total length bus bar installed	102,235 ft.
Total length conduit installed	403,970 ft.

Started to excavate May 3, 1924.

First bloom rolled in 44″ Mill December 31, 1925.

First I-Beam rolled 36″ & 28/32″ Mill January 7, 1926.

First Ingot rolled 54″ Mill November 10, 1926.

First Carnegie Beam rolled December 30, 1925.

MR. E. C. GAINSBORG, Engineer, SKF Industries, Inc., New York; Author "Anti-Friction Bearings on Roll Necks of Rolling Mills."

GORDON FOX, Elec. Engr., Freyn Engineering Co., Author "Electric Power in the Iron and Steel Industry: Generation or Purchase."

A. REICHERT, Elec. Supt., The Bourne Fuller Company, Author "Rehabilitation of Steel Plants."

MR. FRED WALDORF, Dist. Mgr. Steel Mill Div., Timken Roller Bearing Company, Canton, Ohio, Author "Application of Tapered Roller Bearings on Roll Necks of Rolling Mills and Pinion Stands."

J. H. VAN CAMPEN, Chief Engr., E. W. Bliss Co., Author "Radical Improvements on Rolling Mills."

Pittsburgh, Pa.,
June 1st, 1927.

Dear Member:

This letter is the last message that we will be able to send you before the Twenty-Third Annual Convention and Iron and Steel Exposition, which opens June 13th, 1927, at the Syria Mosque, Pittsburgh, Pa.

Your Executive Officers and your Committees have all worked diligently in order to make your Convention and Exposition a success.

You are now asked to study the June issue of the Iron and Steel Engineer very carefully, as this issue contains all of the official programs of the Convention and Exposition, the advance papers which are to be presented at the technical sessions, the editorials prepared by the engineers of the Iron and Steel Industry, the official list of the exhibitors and their booth numbers, and other matters of importance.

Your attention is invited to pages 323 to 428, inclusive. The manufacturers whose apparatus is used in the Iron and Steel Industry all have a message for you, which you cannot afford to overlook. These manufacturers are advising you what the improvements and advances have been in the equipment that you use to produce your enormous tonnages of Iron and Steel.

Your officers and the Chairmen of the various technical sessions all ask your cooperation in prompt attendance at the various sessions and functions that the program provides. All of the technical sessions will start promptly at 10:00 A. M. They will all be held at the Annex of the Pittsburgh Athletic Association, which is about fifty feet from the Syria Mosque, located on the Bigelow Boulevard.

One of the leading features of the Convention week is the inspection trip to Homestead Steel Works, Carnegie Steel Co., Munhall, Pa. The members and guests of the A. I. & S. E. E. will assemble at the Syria Mosque, not later than 11:30 Thursday morning, as the Transportation Committee has arranged to have the street cars leave at 12 o'clock noon. You should not fail to send in your reservation for this trip, so that we will be able to make the proper arrangements for your convenience and comfort.

Monday noon at 12:30 there will be an Informal Reception together with a luncheon at the Annex of the Pittsburgh Athletic Association. You are cordially invited and urged to attend this Reception as this will present an opportunity for you to meet new friends and visit with your old ones.

After you have registered at your hotel come to the official Association headquarters, which is the Annex of the Pittsburgh Athletic Association where you are invited to make your headquarters for the entire week. The Association registration booth will be open at 8:00 o'clock Monday morning.

Syria Mosque, Association Headquarters, Webster Hall, and Schenley Hotel are all located in the Oakland District and may be reached by any street car going out Fifth Avenue, with exception of car number 81. Those persons stopping at the Schenley Hotel or Webster Hall are within one block of the Exposition and Association headquarters.

Do not overlook the fact that the first technical session starts at 10:00 o'clock Monday, June 13th.

The Executive Officers, The Board of Directors, The Chairmen and members of all committees desire to assure you that the Twenty-third Annual Convention and Iron and Steel Exposition will be the biggest, best and most successful in the history of our Society. Help to make it so.

Yours very truly,

ASSOCIATION OF IRON & STEEL ELECTRICAL ENGINEERS,
BOARD OF DIRECTORS,
NATIONAL AND DISTRICT COMMITTEES.